

LOAN DOCUMENT

		PHOTOGRAPH THIS SHEET		①
		LEVEL		
DTIC ACCESSION NUMBER	Draft Work Plan for a Treatability Study...			INVENTORY
	DOCUMENT IDENTIFICATION Feb 95			
DISTRIBUTION STATEMENT A Approved for Public Release Distribution Unlimited				
DISTRIBUTION STATEMENT				
ACCESSION FOR NTIS <input type="checkbox"/> GRAM <input type="checkbox"/> DTIC <input type="checkbox"/> TRAC <input type="checkbox"/> UNANNOUNCED <input type="checkbox"/> JUSTIFICATION <input type="checkbox"/>				
BY				
DISTRIBUTION/				
AVAILABILITY CODES				
DISTRIBUTION				
A-1		DATE ACCESSIONED		
DISTRIBUTION AND/OR SPECIAL				
DISTRIBUTION STAMP		DATE RETURNED		
20001227 001				
DATE RECEIVED IN DTIC				
		REGISTERED OR CERTIFIED NUMBER		
PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC				

H
A
N
D
L
E

W
I
T
H

C
A
R
E

**Draft Work Plan for a
Treatability Study in Support of the
Intrinsic Remediation (Natural Attenuation) Option
at Site 1 (Hazardous Waste Storage Area)**



**Rickenbacker Air National Guard Base
Lockbourne, Ohio**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**Rickenbacker Air National Guard Base
Lockbourne, Ohio**

February 1995

AQ MOI-03-0657

DEFENSE TECHNICAL INFORMATION CENTER REQUEST FOR SCIENTIFIC AND TECHNICAL REPORTS		
Title <u>AFCEE Collection</u>		
1. Report Availability (Please check one box) <input checked="" type="checkbox"/> This report is available. Complete sections 2a - 2f. <input type="checkbox"/> This report is not available. Complete section 3.	2a. Number of Copies Forwarded <u>1 each</u>	2b. Forwarding Date <u>July/2000</u>
2c. Distribution Statement (Please check ONE box) DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly below. Technical documents MUST be assigned a distribution statement. <input checked="" type="checkbox"/> DISTRIBUTION STATEMENT A: Approved for public release. Distribution is unlimited. <input type="checkbox"/> DISTRIBUTION STATEMENT B: Distribution authorized to U.S. Government Agencies only. <input type="checkbox"/> DISTRIBUTION STATEMENT C: Distribution authorized to U.S. Government Agencies and their contractors. <input type="checkbox"/> DISTRIBUTION STATEMENT D: Distribution authorized to U.S. Department of Defense (DoD) and U.S. DoD contractors only. <input type="checkbox"/> DISTRIBUTION STATEMENT E: Distribution authorized to U.S. Department of Defense (DoD) components only. <input type="checkbox"/> DISTRIBUTION STATEMENT F: Further dissemination only as directed by the controlling DoD office indicated below or by higher authority. <input type="checkbox"/> DISTRIBUTION STATEMENT X: Distribution authorized to U.S. Government agencies and private individuals or enterprises eligible to obtain export-controlled technical data in accordance with DoD Directive 5230.25, Withholding of Unclassified Technical Data from Public Disclosure, 6 Nov 84.		
2d. Reason For the Above Distribution Statement (in accordance with DoD Directive 5230.24)		
2e. Controlling Office <u>HQ AFCEE</u>	2f. Date of Distribution Statement Determination <u>15 Nov 2000</u>	
3. This report is NOT forwarded for the following reasons. (Please check appropriate box) <input type="checkbox"/> It was previously forwarded to DTIC on _____ (date) and the AD number is _____ <input type="checkbox"/> It will be published at a later date. Enter approximate date if known. _____ <input type="checkbox"/> In accordance with the provisions of DoD Directive 3200.12, the requested document is not supplied because: _____		
Print or Type Name <u>Laura Peña</u> Telephone <u>210-536-1431</u>	Signature <u>Laura Peña</u> (For DTIC Use Only) AQ Number <u>MD-03-0657</u>	

DRAFT

WORK PLAN FOR A
TREATABILITY STUDY
IN SUPPORT OF THE INTRINSIC REMEDIATION
(NATURAL ATTENUATION) OPTION
AT SITE 1 (HAZARDOUS WASTE STORAGE AREA)

at

RICKENBACKER AIR NATIONAL GUARD BASE
LOCKBOURNE, OHIO

February 1995

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

OHIO AIR NATIONAL GUARD
RICKENBACKER AIR NATIONAL GUARD BASE
LOCKBOURNE, OHIO

Prepared by:

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

CONTENTS

1	INTRODUCTION.....	1-1
1.1	SCOPE OF CURRENT WORK PLAN.....	1-2
1.2	BACKGROUND	1-2
1.2.1	Base Mission and Surrounding Land Use.....	1-3
1.2.2	Site History.....	1-3
1.2.3	Previous Site Investigations	1-7
2	DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT	2-1
2.1	DATA REVIEW	2-1
2.1.1	Topography, Surface Hydrology, and Climate	2-1
2.1.2	Overview of Geology and Hydrogeology	2-3
2.1.3	Soil Quality	2-9
2.1.4	Ground Water Quality and Chemistry	2-16
2.2	Development of Conceptual Model	2-16
2.2.1	Intrinsic Remediation and the Bioplume II Model.....	2-20
2.2.2	Biodegradation of Dissolved BTEX Contamination.....	2-21
2.2.3	Biodegradation of Dissolved Chlorinated Solvent Contamination.....	2-22
2.2.4	Initial Conceptual Models	2-22
2.2.5	Potential Pathways and Receptors.....	2-23
3	COLLECTION OF ADDITIONAL DATA.....	3-1
3.1	CONE PENETROMETRY.....	3-3
3.1.1	CPT/LIF Testing Strategy	3-4
3.1.2	Soil Sampling and Analysis	3-7
3.1.3	CPT Locations and Datum Survey.....	3-8
3.1.4	Site Restoration	3-8
3.1.5	Equipment Decontamination Procedures	3-8
3.2	PERMANENT MONITORING POINT INSTALLATION.....	3-10
3.2.1	Monitoring Point Locations and Completion Intervals.....	3-10
3.2.2	Monitoring Point Installation Procedures	3-11
3.2.3	Site Restoration	3-14
3.3	GROUNDWATER SAMPLING.....	3-16
3.3.1	Preparation for Sampling	3-17
3.3.2	Sampling Procedures.....	3-17
3.3.3	Onsite Ground Water Parameter Measurement.....	3-21
3.4	SAMPLE HANDLING FOR LABORATORY ANALYSIS	3-23
3.4.1	Sample Preservation.....	3-24
3.4.2	Sample Container and Labels.....	3-24
3.4.3	Sample Shipment	3-24
3.4.4	Chain-of-Custody Control.....	3-25
3.4.5	Sampling Records	3-25
3.4.6	Laboratory Analyses	3-25
3.5	AQUIFER TESTING.....	3-26
3.5.1	Definitions.....	3-26
3.5.2	Equipment	3-27

3.5.3 General Test Methods	3-27
3.5.4 Falling Head Test	3-27
3.5.5 Rising Head Test	3-28
3.5.6 Slug Test Data Analysis	3-30
4 REMEDIAL OPTION EVALUATION AND TS REPORT	4-1
5 QUALITY ASSURANCE/QUALITY CONTROL	5-1
6 REFERENCES.....	6-1

APPENDIX A CONTAINERS, PRESERVATIVES, PACKAGING, AND
SHIPPING REQUIREMENTS FOR GROUND WATER
SAMPLES

APPENDIX B ADDITIONAL SITE DATA

TABLES

	Page
1.1 Summary of Wastes Stored at Site 1 (HWSA)	1-8
2.1 Summary of Monitoring Well Construction Details	2-8
2.2 Summary of Ground Water Level and Free Product Measurements	2-10
2.3 Summary of Soil Analytical Data	2-14
2.4 Summary of Ground Water Analytical Data	2-18
3.1 Analytical Protocol for Ground Water and Soil	3-2
4.1 Example TS Report Outline	4-2
5.1 QA/QC Sampling Program	5-2

FIGURES

	Page
1.1 Regional Location Map	1-4
1.2 Site Location Map	1-5
1.3 Site Layout Map	1-6
2.1 Regional Topographic Map	2-2
2.2 Location of Hydrogeologic Cross Sections	2-5
2.3 Generalized Hydrogeologic Cross Section A - A'	2-6
2.4 Generalized Hydrogeologic Cross Section B - B'	2-7
2.5 Water Table Elevation Map - February 1990	2-11
2.6 Estimated Areal Extent of Total BTEX Contamination for Soil	2-12
2.7 Monitoring Wells and Screening Locations	2-17
2.8 Estimated Extent of Total BTEX Contamination in Ground Water -1990	2-19
3.1 Cross Section of Fiber Optic Fluorometry Penetrometer	3-5
3.2 Proposed Cone Penetrometer and Ground Water Sampling Locations.....	3-6
3.3 Geologic Boring Log.....	3-9
3.4 Monitoring Point Installation Record	3-13
3.5 Monitoring Point Development Record.....	3-15

FIGURES (Continued)

	Page
3.6 Ground Water Sampling Record	3-18
3.7 Aquifer Slug Test Data Form	3-29

SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering-Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with petroleum hydrocarbons and chlorinated organic compounds located at Site 1 (Hazardous Waste Storage Area) at Rickenbacker Air National Guard Base (the Base), in Lockbourne, Ohio.

Several remedial options will be evaluated during the TS, including free product removal; bioventing for source removal; air sparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. All hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is primarily oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II groundwater model in support of intrinsic remediation for restoration of fuel-hydrocarbon-contaminated groundwater.

As part of the TS, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible threat to potential downgradient receptors; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The Bioplume II modeling effort for this site will involve completion of several tasks, which are described in the following sections.

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), US Environmental Protection Agency (EPA), Ohio Environmental Protection Agency (OEPA), the Rickenbacker Base Conversion Agency, and Parsons ES at a meeting conducted at the Base on February 2, 1995; on the statement of work (SOW) for this project; and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993b) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and the Base.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for remediation of groundwater contamination at Site 1. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with EPA and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in groundwater, and to model this degradation using the Bioplume II numerical groundwater model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities to be performed in support of the TS and the Bioplume II modeling effort.

Proposed site characterization activities in support of the TS include: 1) determination of preferential contaminant migration pathways; 2) cone penetrometer (CPT) and laser-induced fluorescence (LIF) testing; 3) groundwater monitoring point placement; 4) soil and groundwater sampling; and 5) aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site obtained from widely accepted published literature will be used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated using historical site data. Upon completion of the Bioplume II modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate groundwater remedial technology based on available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for groundwater samples. Appendix B contains a summary of existing soil and groundwater analytical data from previous field investigation work.

1.2 BACKGROUND

The Base, which covers approximately 2,100 acres in Franklin and Pickaway Counties, Ohio, lies 12 miles southeast of Columbus, and 0.5 mile east of Lockbourne,

Ohio (Figure 1.1). The Base is situated on a glacial till plain between the Big Walnut and Walnut Creek drainage basins (ES, 1993a).

1.2.1 Base Mission and Surrounding Land Use

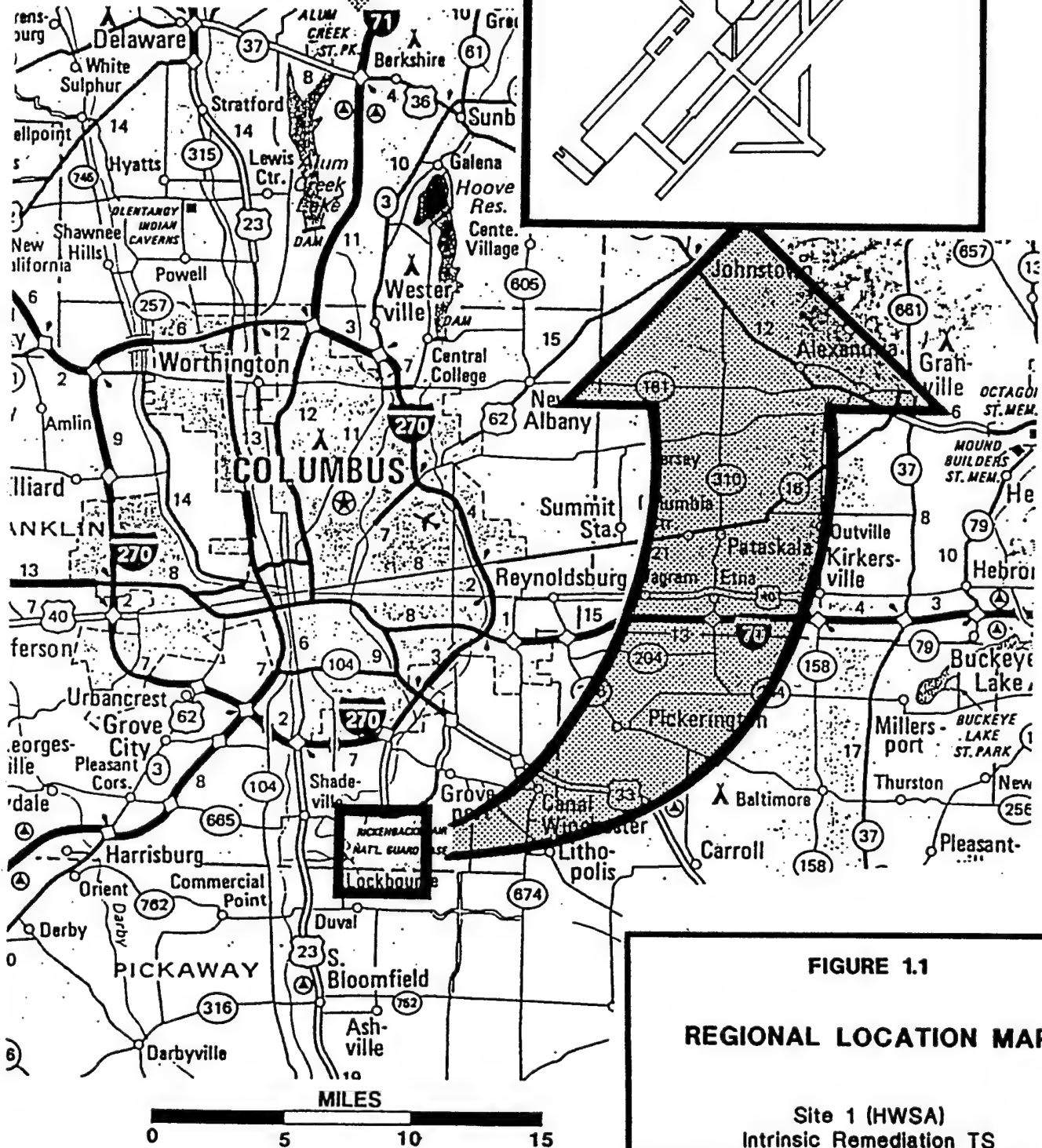
Rickenbacker Air National Guard Base, known as Lockbourne Air Force Base until 1974, was officially activated as the Northeastern Training Center, Army Air Corps, in 1942. The Base was used as an air base under the control of various government agencies, including the Strategic Air Command, the Ohio Air National Guard (OANG), and the Army Air Corps. The Base closed in April 1980, and was turned over to the OANG. Portions of the Base have been under the ownership of the Rickenbacker Port Authority (RPA) since 1982, and are used by private aircraft. The Base is slated for closure, and access to it is restricted (ES, 1992b).

Land use in the area of the Base is residential and agricultural. The military personnel housing in the northwestern corner of the Base has been purchased by a private developer, and units have been rented and/or sold to civilians. Open agricultural land lies to the north and east of the Base, with some residential development along the creeks and major roads. Privately owned trailer parks and single family homes lie to the south of the Base on the former Base golf course (ES, 1992b).

1.2.2 Site History

Site 1, the Hazardous Waste Storage Area (HWSA) is located at the edge of the shop area in the central section of the Base (Figure 1.2). Site 1 measures approximately 150 feet by 95 feet and is surrounded by a chain-link fence with a locking gate. Site 1 consists of Building 560 and the drum storage area (DSA) east and southeast of the building. A 25,000-gallon underground storage tank (UST) southeast of the DSA and three adjacent 25,000-gallon USTs located outside of the fence surrounding Site 1 were recently removed. Three additional abandoned 25,000-gallon USTs are located northeast of the road. Two abandoned separator pits lie to the north of the USTs. Another abandoned pit lies northeast of the road. Figure 1.3 presents a site map of Site 1. Previous investigations identified the four removed 25,000-gallon USTs, the separator pits, and the DSA as potential sources of the contamination (ES, 1992a and 1992b).

Site 1 has been under a permit for hazardous waste storage since 1983, but no waste has been stored at the facility since September 1986. Prior to 1983, Building 560 housed water demineralization equipment. The conversion of the site into a hazardous waste storage facility involved sealing off all floor drains that lead to storm sewers, connecting remaining drains to the sanitary sewer, and installing emergency eye-wash and shower fixtures. Until 1986, Building 560 was used to store small containers of hazardous waste. The DSA adjacent to Building 560 was used to store 55-gallon drums containing liquid wastes associated with degreasing operations at Base shops, aircraft cleaning, and general maintenance. These wastes included solvents, cleaning fluids, acids, and paint strippers. Small quantities of dry wastes such as desiccants were stored in Building 560. As many as 165 containers were stored at one time in the

**FIGURE 1.1**

REGIONAL LOCATION MAP

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio

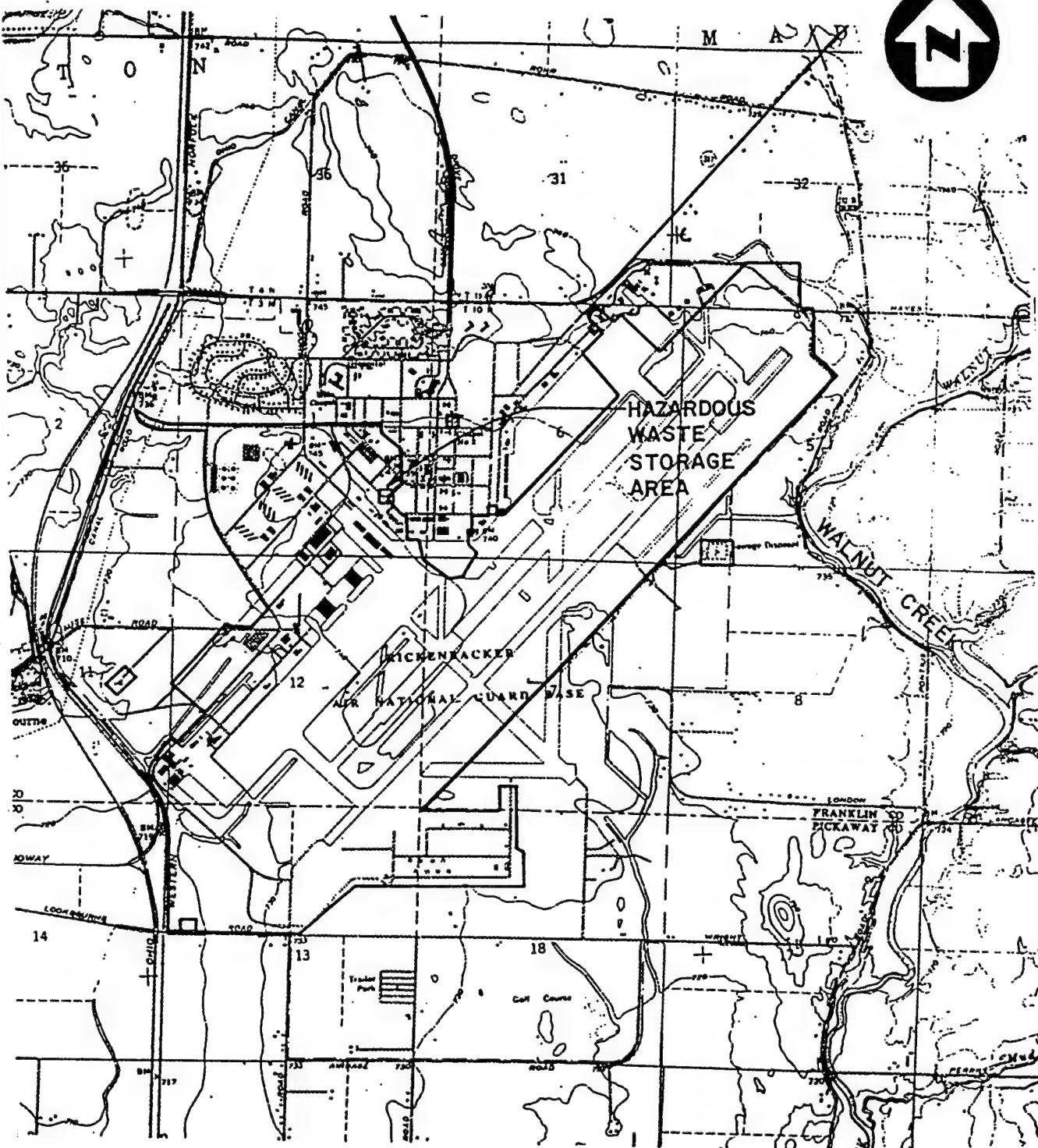


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Source: ES, 1992b

M:\45025\DRAWINGS\95DN0132, 2/13/95 at 7:45



2000 1000 0 1000 2000 feet
SCALE

— BASE
BOUNDARY

FIGURE 1.2

SITE LOCATION MAP

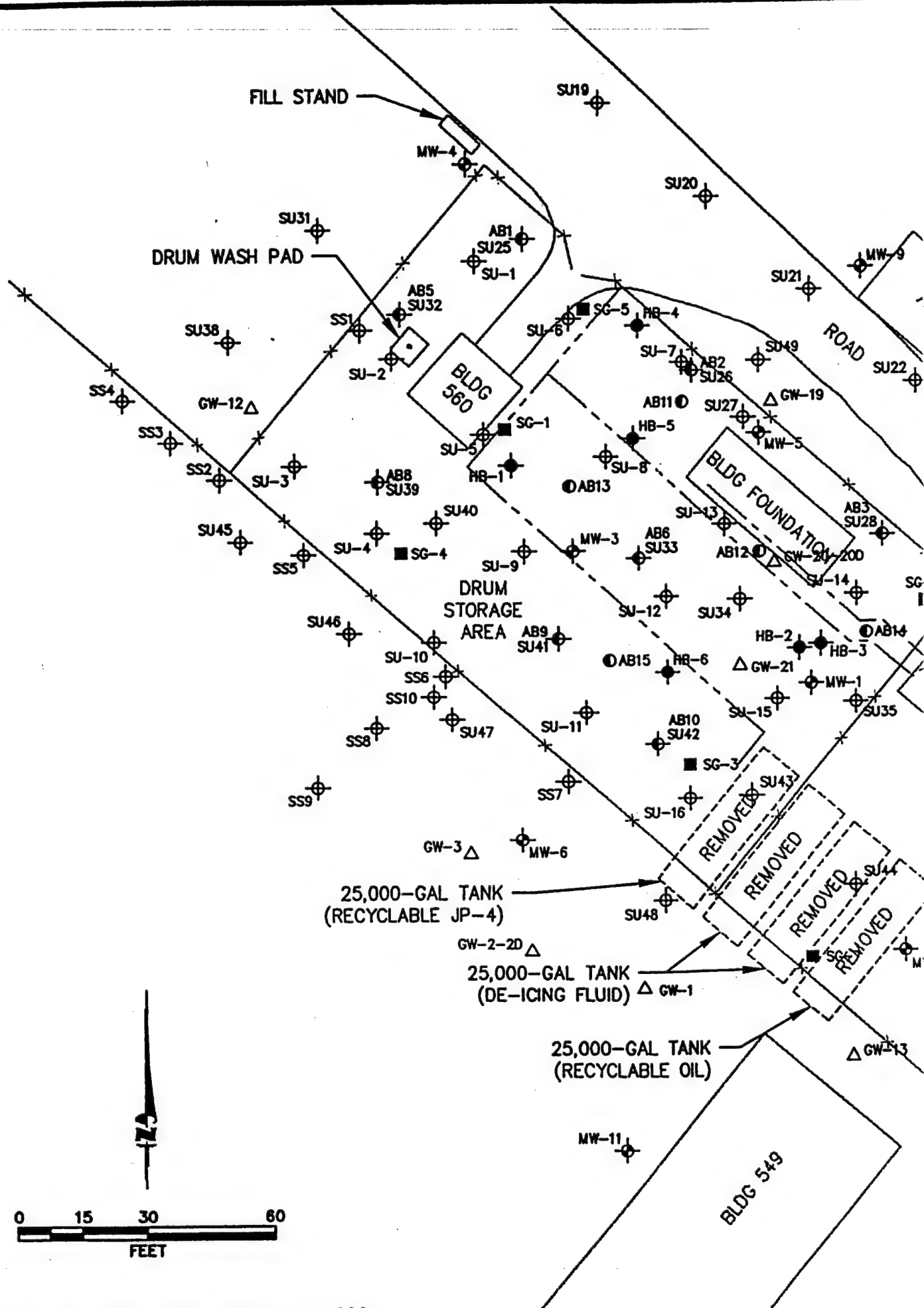
Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Source: ES, 1992b

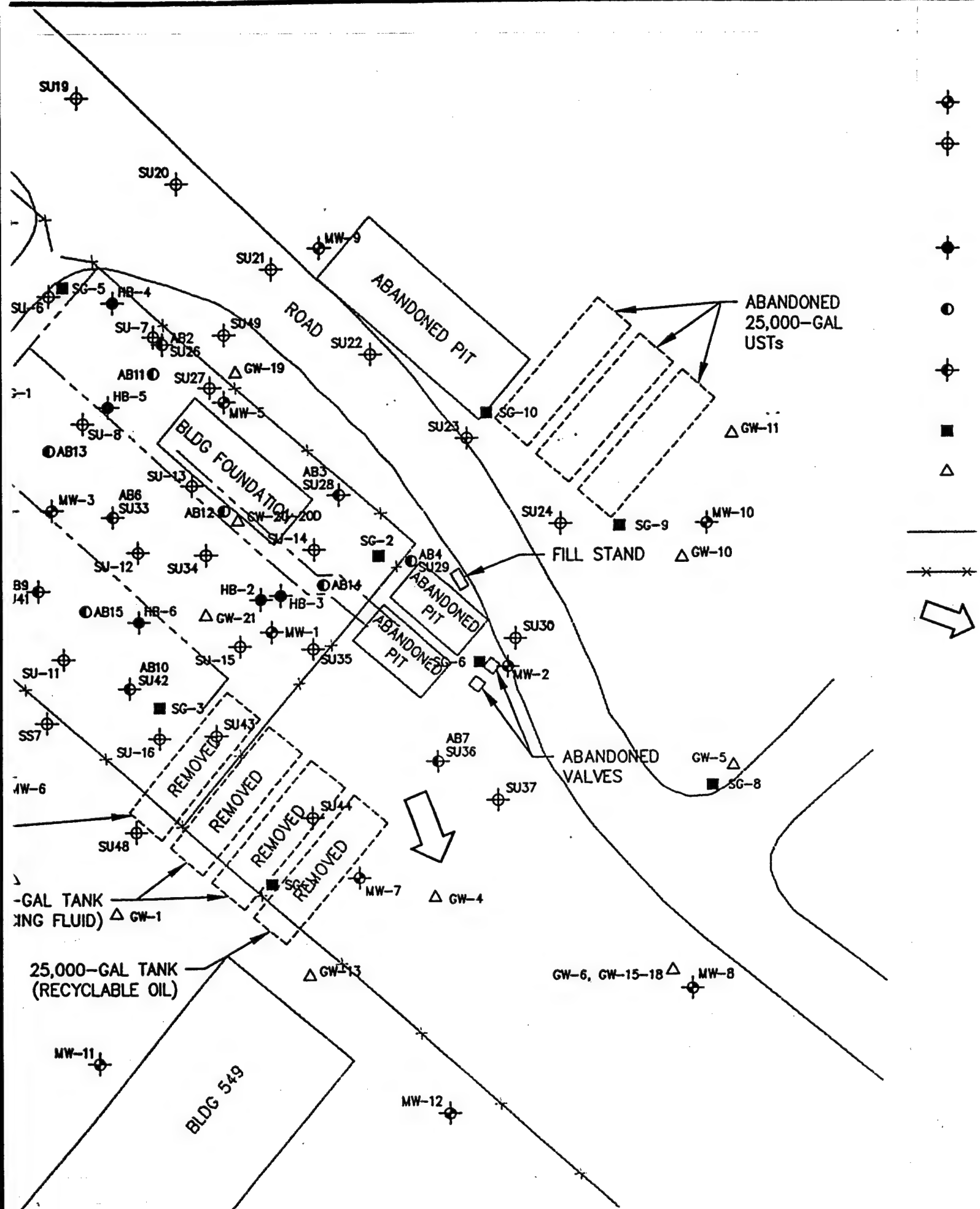
M: \45025\DRAWINGS\95DN0132, 2/13/95 at 7:45



Source: ES, 1989, 1992a, 1992b and 1992c

M: \45025\DRAWINGS\95DN0122, 2/13/95 at 9:30

①



LEGEND



MONITORING WELL LOCATION



SURFACE SOIL SAMPLING LOCATION
(SU1 TO SU16, JULY 1988)
(SU19 TO SU49, JANUARY 1990)
(SS1 TO SS10, OCTOBER 1990)



HAND-AUGERED BORING LOCATION
(JULY 1988)



SHALLOW SOIL BOREHOLE
(JANUARY 1990)



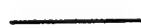
SHALLOW AND DEEP SOIL BOREHOLE
(JANUARY 1990)



SOIL GAS SAMPLING LOCATION



GROUND WATER SCREENING LOCATION
(OCTOBER 1991)



ABANDONED FUEL LINE



FENCE



GROUND WATER FLOW
DIRECTION

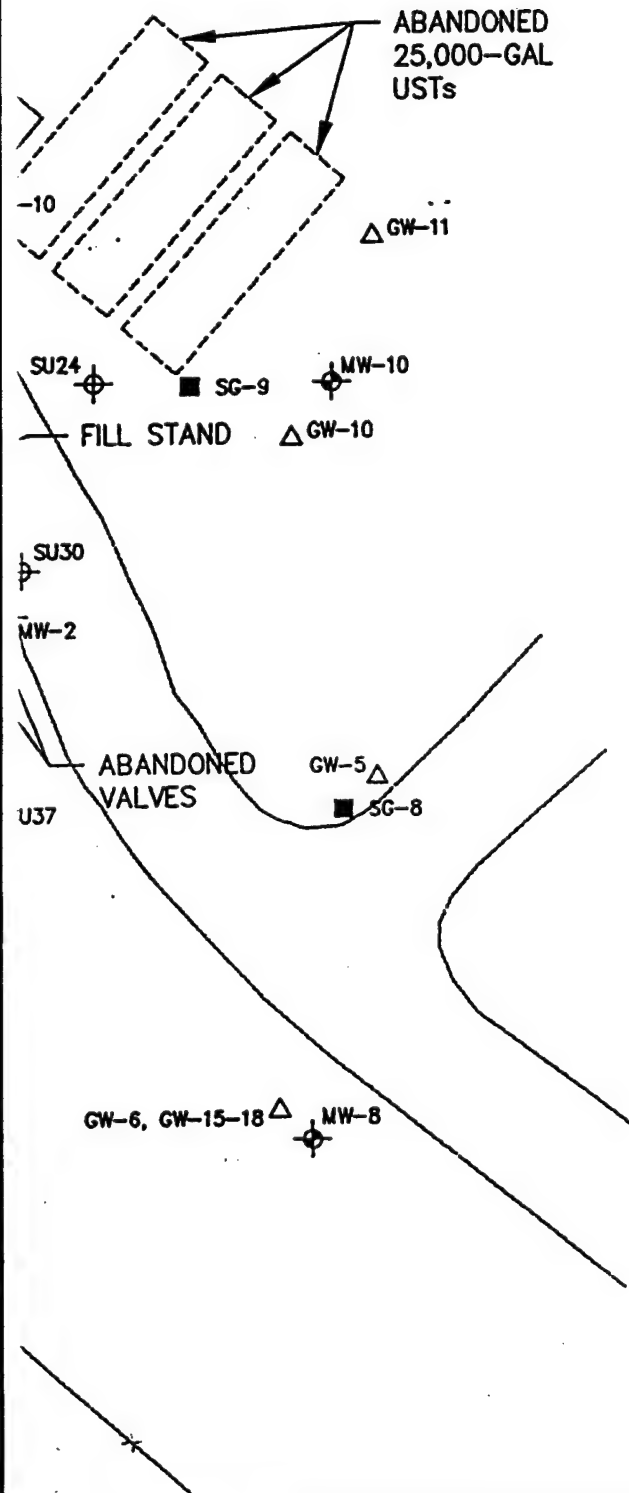


FIGURE 13

SITE LAYOUT MAP

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

grass area near Building 560. Table 1.1 presents a summary of the waste stored at the DSA. The four 25,000-gallon steel USTs, which were recently removed, were used for approximately 40 years. Two of these USTs were utilized for the storage of non-hazardous de-icing fluid. The other two USTs were used to store oil and recyclable JP-4 jet fuel. The JP-4 and oil USTs were taken out of service in 1988. Dielectric fluid, which may contain polychlorinated biphenyls (PCBs), was stored in the waste oil UST. The only recorded loss from any of the storage tanks occurred when a standpipe broke in 1982. No record of the amount of waste released is available (ES, 1989, 1992a, 1992b, 1992c, and 1993a).

1.2.3 Previous Site Investigations

Installation Restoration Program (IRP) action was initiated by the Department of Defense (DOD), the Air National Guard (ANG), and the US Air Force (USAF) at the Base in 1987. The ANG, through a technical agreement with the USAF and the Department of Energy (DOE), retains Martin Marietta Energy Systems Inc. (MMES) to conduct the Hazardous Waste Remedial Actions Program (HAZWRAP) at ANG sites. MMES subcontracted site investigation (SI) activities to ES (1989, 1992a, 1992b, and 1993a) in 1988.

Site 1 was identified as a potential source of contamination in the preliminary Assessment (PA) of the Base in 1987 (Hazardous Materials Technical Center [HMTTC], 1987). Initial SI activities were conducted by ES based on the results of the PA. During field activities associated with the first phase of the SI, a soil gas survey was conducted at 9 locations (1SG-1 to 1SG-9) in July 1988. In July and August 1988, soil samples were collected from 16 surface locations (SU-1 to SU-16), 6 shallow hand-augered borings (HB-1 to HB-6), and 3 hollow stem auger borings. The 3 hollow stem auger borings were completed as monitoring wells (MW-1 to MW-3). Aquifer slug tests were performed in each of the three monitoring wells. A closure plan for the Base was approved by the Ohio Environmental Protection Agency (OEPA) in September 1989. The field investigation report (FIR) for the first phase of the SI was completed by ES (1989) in October 1989. In January 1990, during pre-closure SI activities, 31 surface soil samples (SU-19 through SU-49) were collected, and 10 shallow soil borings (AB-1 to AB-10) and 5 deep soil borings (AB-11 through AB-15) were installed. Six additional soil borings were completed as monitoring wells (MW-4 through MW-9). Aquifer slug tests were performed on 4 of the 6 monitoring wells installed during the pre-closure site investigation.

In July 1990, field activities associated with the determination of the extent of phase-separated hydrocarbons (PSH) were conducted. Soil was excavated around the USTs, the abandoned separator pits, and in areas outside Site 1, and a soil gas survey was performed. In October 1990, the draft pre-closure sampling report (PCSR) was completed by ES. Groundwater screening for volatile organic compounds (VOCs) was performed at 18 locations (GW-1 through GW-21) in October 1991 as part of the addendum to the PCSR (ES, 1992a). As a result of this VOC screening, three additional soil borings were completed as monitoring wells (MW-10, MW-11, and MW-12). Ten surface soil samples (SS1 through SS10) were also collected as part of the addendum to the PCSR. The final Addendum to the PCSR was submitted to the

TABLE 1.1
SUMMARY OF WASTES STORED AT SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Waste Description	EPA Haz. Waste Number	Quantity (gallons)			
		1983	1984	1985	1986 ^{a/}
PD 680 (Stoddard Solvent, Flammable Aliphatic Petroleum Distillate)	D001	1,155	1450	110	2429
Carbon Removing Compound (Methylene Chloride, Creosols, Phenols)	F001, F004	590	870		
HAN (Highly Aromatic Naptha)	D001	500	290		
MEK (Methyl Ethyl Ketone)	F005	285	525		1050
Paint Remover	F005	200	540		
Bromochloromethane		200	385		
Sulfuric Acid	D002	25	25		
Paint Thinner	D001	20	20		
Ethanolamine and Benzyl Alcohol	D001	220			
Oily Water and Cleaning Solutions containing Lead, Cadmium, Chromium and Nickel	D006, D007, D008	495			
Hydraulic Fluid			360		
Synthetic Oil			440		
Inspection Penetrant			150		
Organic Peroxide	D002			1	
Spent Desiccant (Cobalt chloride) ^{b/}		50	40	10	

Source: ES, 1993a

^{a/} 1986 storage in pounds

^{b/} Desiccant quantities for all years in pounds

ANG in January 1992 and a final PCSR was completed by ES (1992b) in March 1992. The PSH report was also completed in March 1992 (ES, 1992c). In March 1993, an amended closure/post closure plan was submitted by ES (1993a) to the ANG.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were reviewed and used to develop conceptual models of the groundwater flow and contaminant transport regimes for Site 1. These conceptual models will allow efficient collection of additional data to support the Bioplume II modeling effort and to evaluate potential remediation technologies, including intrinsic remediation. Sections 2.1 and 2.2 present a synopsis of available site data. Section 2.3 presents the preliminary conceptual groundwater flow and solute transport models that were developed based on these data.

2.1 DATA REVIEW

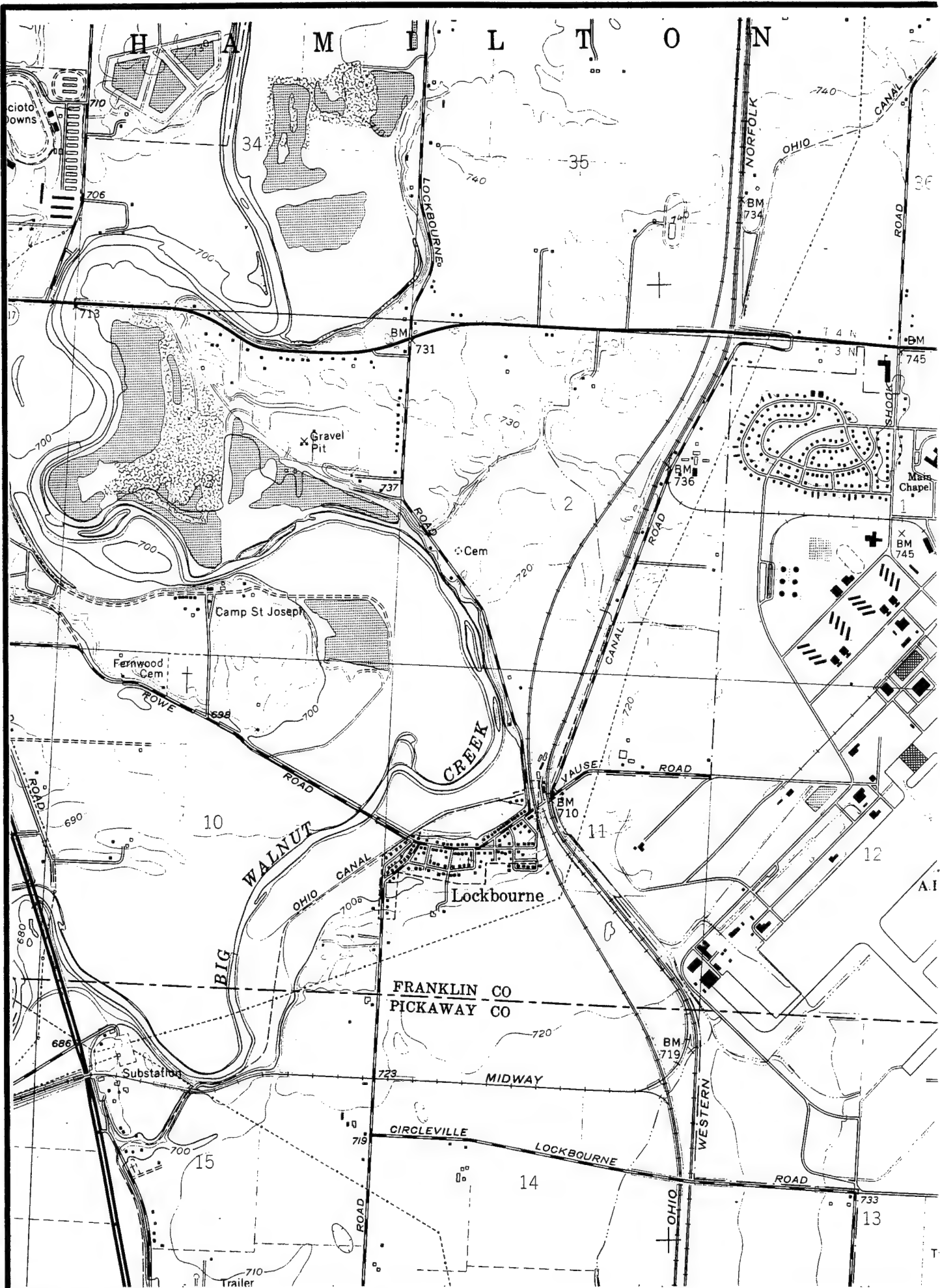
The following sections were based upon review of data from the following sources:

- Field Investigation Report (ES, 1989)
- Addendum to the Pre-Closure Sampling Report (ES, 1992a);
- Pre-Closure Sampling Report (ES, 1992b);
- Determination of Phase-Separated Hydrocarbon Contamination (ES, 1992c); and
- Amended Closure/Post Closure Plan (ES, 1993a).

2.1.1 Topography, Surface Hydrology, and Climate

The Base is located in the Interior Plains Physiographic Region, just west of the Appalachian Highlands. The Interior Plains Physiographic Region is characterized by broad river valleys with low local relief, separated by large plateaus and rolling hills (Espenshade, 1986). Base elevations range from approximately 720 to 750 feet above mean sea level (msl). Vegetation consists of grasses and herbaceous plants, with deciduous trees along the stream beds (ES, 1989, 1992a, and 1992b). A topographic map of the Base area is presented in Figure 2.1 (US Geological Survey [USGS], 1985)

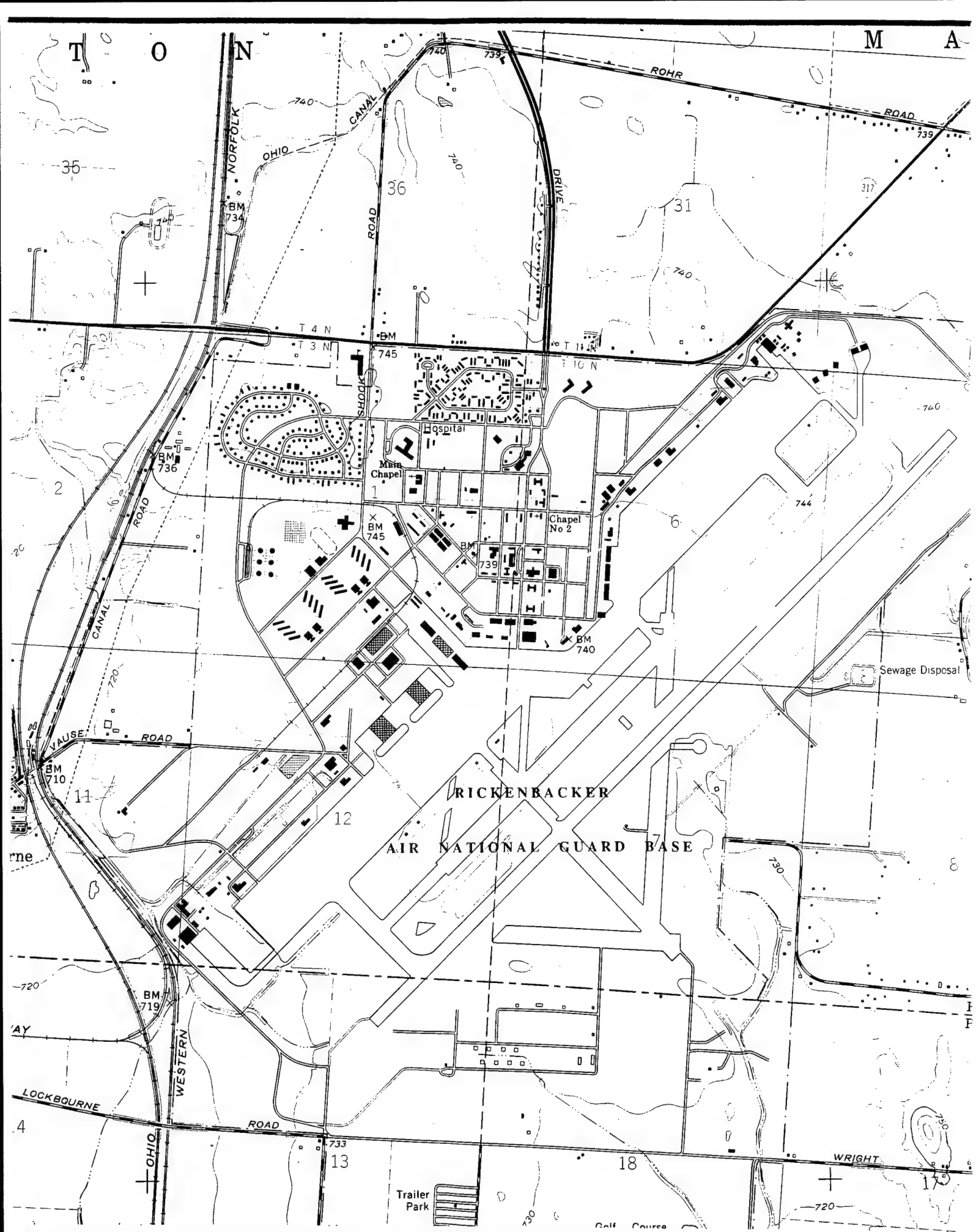
Major surface water features in the area include Big Walnut Creek, located west and north of the Base, and Walnut Creek, located east of the Base. Several intermittent



Source: USGS, 1985

M: \45025\DRAWINGS\95DN0135, 2/7/95 at 9:15

①



streams, which flow into either Big Walnut Creek or Walnut Creek, are located on or near the Base (Figure 2.1). Surface water at the Base and Site 1 is collected through an extensive storm drain network. Water from the storm drains is routed through oil/water separators before being released into the surrounding streams. Surface water originating from Site 1 enters a separator located in the northeastern section of the Base and drains into Walnut Creek near the sewage disposal area (Figure 2.1) (ES, 1989 and 1992a; USGS, 1985).

The climate is continental, characterized by cold winters, hot summers, and moderate rainfall (Pierce, 1959). The mean annual temperature is 52 degrees Fahrenheit (°F). The coldest month is January with a mean temperature of 30°F; the warmest month is July, with a mean temperature of 74°F. Precipitation at the Base occurs primarily during the summer months, with June being the wettest month and October being the driest month of the year. The mean annual Base precipitation is approximately 38 inches (HMTc, 1987).

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional and Local Geology and Hydrogeology

Rickenbacker ANGB lies within the Glaciated Central Lowlands Geologic Province, just west of the Appalachian Plateau Province. The geology of the area is characterized by over 200 feet of Pleistocene sandy and gravelly glacial outwash and silty and clayey glacial till filling a pre-glacial bedrock valley. The bedrock in the area consists of Devonian-age limestones and shales of the Columbus and Delaware Formations (ES, 1993a).

On the Base, surficial deposits consist of 8 to 20 feet of yellowish-brown silt and clay underlain by 2 to 20 feet of medium-grained, sandy gravel with interbedded, intermittent stringers of fine-grained, well-sorted sands and sandy gravels. These sands and gravels form the shallow surficial aquifer beneath the Base. Between 40 and 70 feet of dense, gray silty clay lies beneath the sands and gravels of the surficial aquifer. Intermittent sand and gravel layers exist within the upper portion of the clay unit. Directly beneath the clay unit, at depths ranging from 50 to 100 feet below ground surface (bgs), is 100 to 140 feet of gravel and sand. The bedrock of the Columbus and Delaware Formations is found beneath the lower sand and gravel unit, at a depth of at least 200 feet bgs (ES, 1989, 1992a, 1992b, and 1993a).

The regional hydrogeology of central Ohio is characterized by unconfined and confined surficial aquifers within the glacial deposits overlying confined bedrock aquifers. Yields from the surficial aquifers varies greatly depending upon the glacial materials deposited (Driscoll, 1986)

At the Base, two aquifers exist within the surficial glacial deposits. An unconfined to semiconfined shallow surficial aquifer, consisting of silts, sands, and gravels up to 15 feet thick, is present at depths ranging from 5 to 15 feet bgs. The base of the shallow surficial aquifer is roughly defined by the top of the gray, silty clay confining unit. Previous investigations indicate that the intermittent sands and gravels within the

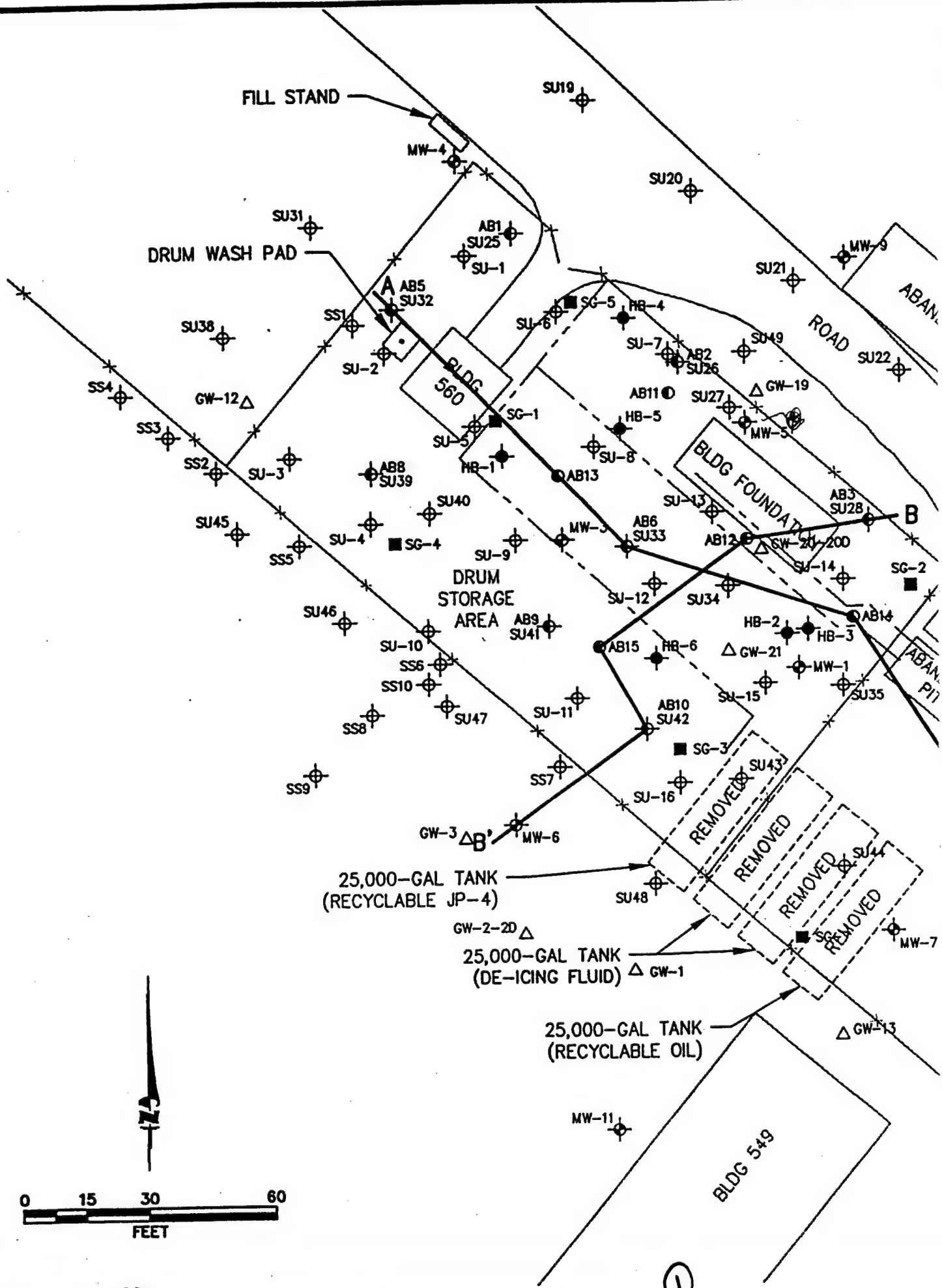
upper portion of the clay unit are also water bearing, but the hydraulic connection between these sand and gravel layers and the shallow, surficial aquifer is not clearly defined. A deep, confined surficial aquifer exists at depths ranging from 50 to 100 feet bgs and is comprised of sands and gravels ranging in thickness from 100 to 140 feet. No information is available concerning groundwater within the bedrock beneath the Base. The deep surficial aquifer serves as a primary source of potable water for the Base and the City of Lockbourne, Ohio (ES, 1989, 1992a, 1992b, and 1993a).

2.1.2.2 Site Geology and Hydrogeology

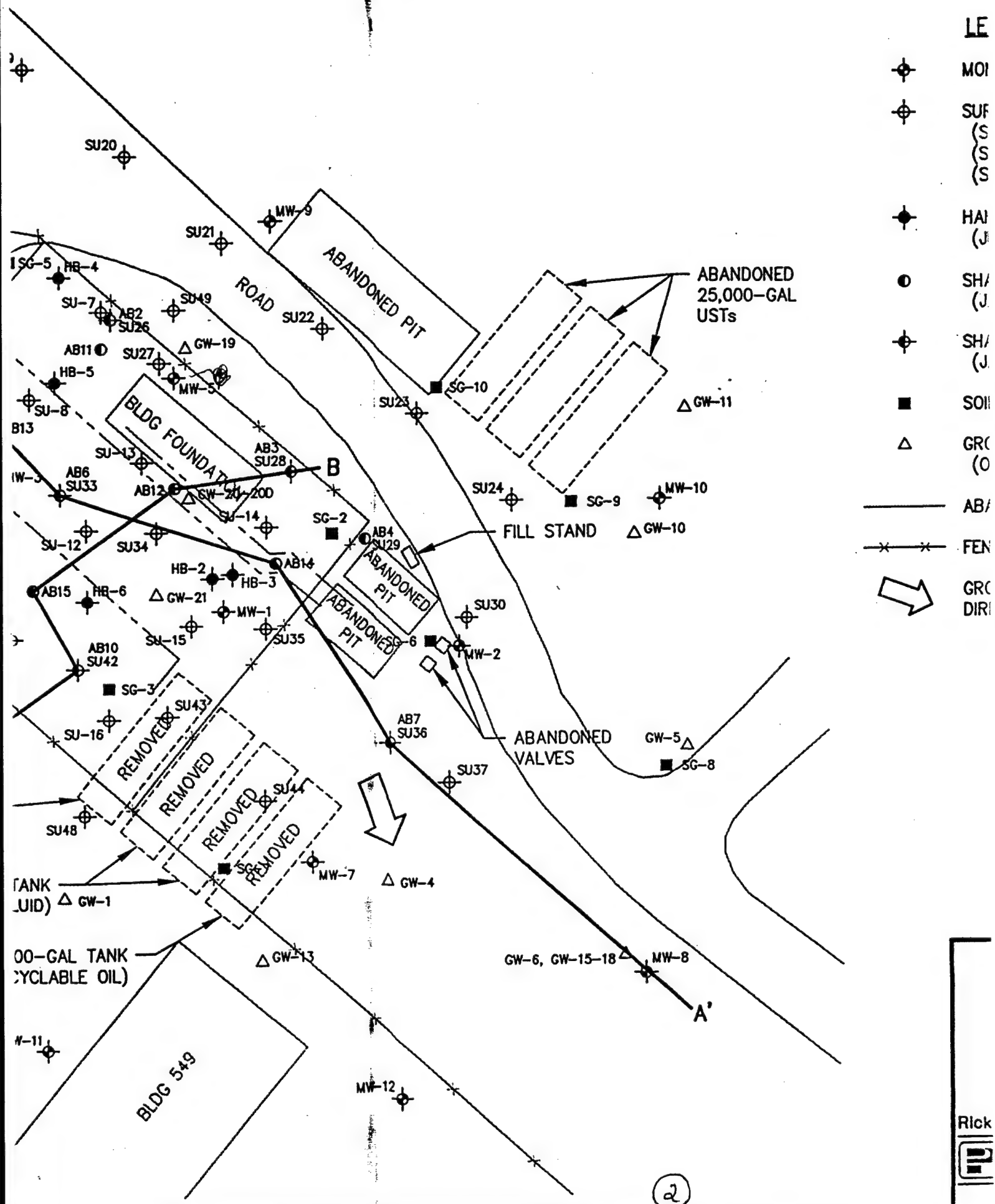
During initial site investigation activities conducted by ES (1989), three borings were installed and sampled using a hollow-stem auger with a split-spoon sampler. Borehole depths ranged from 15 to 20 feet bgs, and all three were completed as monitoring wells. Six additional shallow soil borings were installed, and 16 surface soil samples were collected using manual sampling methods. Each shallow soil boring was completed to a depth of 4 feet bgs. In January 1990, pre-closure field activities performed by ES (1992b) included drilling of six additional borings to 16 feet bgs, using a hollow-stem auger. Each boring was sampled and completed as a monitoring well. Thirty-one surface soil samples were collected at the site in a 35-foot grid pattern to ascertain the areal extent of surface soil contamination. At 10 of the surface soil sampling locations, shallow soil borings were installed to 10 feet bgs using a hollow-stem auger. Samples were collected from these borings to determine the vertical extent of soil contamination. Five deep soil borings were drilled and sampled to depths ranging from 23 to 27 feet bgs.

As part of the PSH investigation conducted by ES (1992c), test pits were excavated to depths of 3 to 12 feet bgs in four potential source areas. Three additional soil borings were drilled and sampled to a depth of 18 feet, then completed as monitoring wells as part of the supplementary investigation associated with the PCSR (ES, 1992b). As part of the addendum to the PCSR, 10 additional surface soil samples were gathered along the southern edge of Site 1. The locations of hydrogeologic cross-section lines are shown in Figure 2.2. Figures 2.3 and 2.4 present the hydrogeologic cross sections developed from boring logs produced during initial and pre closure site investigation efforts. Table 2.1 presents the well completion data for Site 1.











Near-surface soil observed in the vicinity of Site 1 consisted of yellowish-brown, silt and silty clay to a depth ranging from 8 to 15 feet bgs. The relatively low vertical and horizontal permeability of the silt and clays is thought to retard the migration of surface contaminants into groundwater. Beneath the surficial silt and clay layer is 2 to 10 feet of brown to reddish-brown, medium-grained sandy gravel with stringers of fine-grained, well-sorted sands and sandy gravels. No further subsurface information at Site 1 is available, but it is assumed that subsurface geology is similar to that of the rest of the Base, as described in Section 2.1.2.1 (ES, 1989, 1992a, 1992b, and 1992c).



Source: ES, 1992a



LEGEND

-  MONITORING WELL LOCATION
-  SURFACE SOIL SAMPLING LOCATION
(SU1 TO SU16, JULY 1988)
(SU19 TO SU49, JANUARY 1990)
(SS1 TO SS10, OCTOBER 1990)
-  HAND-AUGERED BORING LOCATION
(JULY 1988)
-  SHALLOW SOIL BOREHOLE
(JANUARY 1990)
-  SHALLOW AND DEEP SOIL BOREHOLE
(JANUARY 1990)
-  SOIL GAS SAMPLING LOCATION
-  GROUND WATER SCREENING LOCATION
(OCTOBER 1991)
-  ABANDONED FUEL LINE
-  FENCE
-  GROUND WATER FLOW
DIRECTION

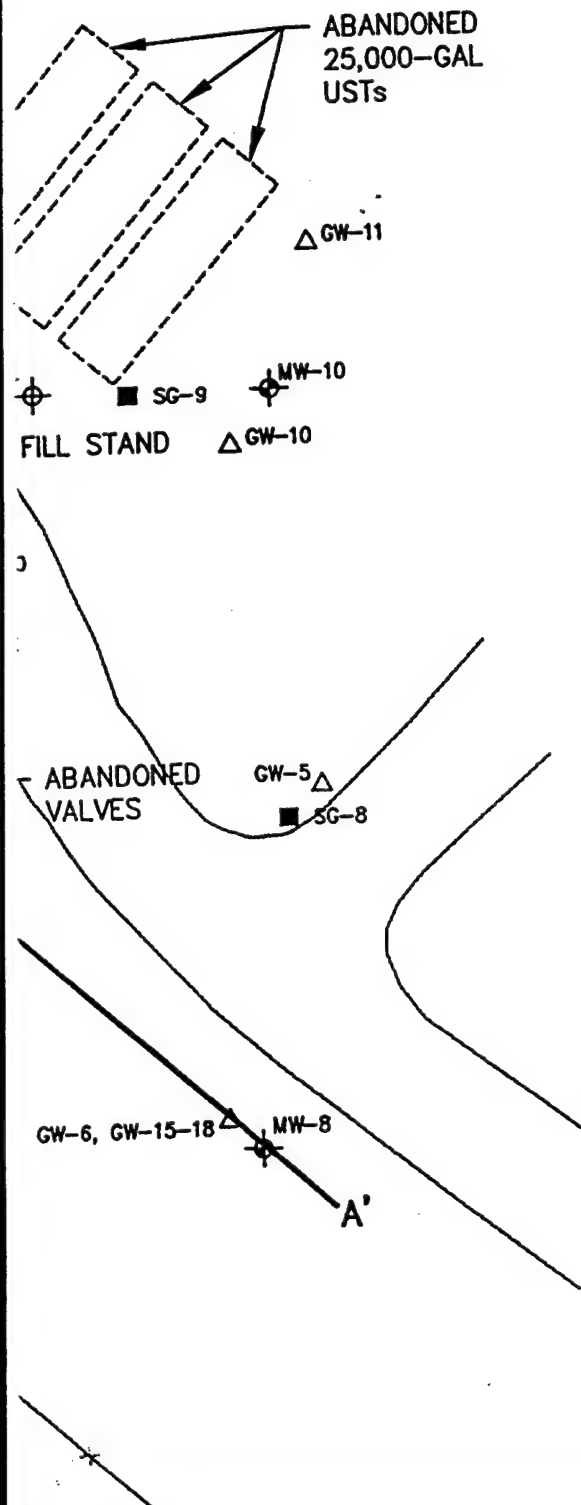


FIGURE 2.2

LOCATION OF GEOLOGIC CROSS SECTIONS

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

3

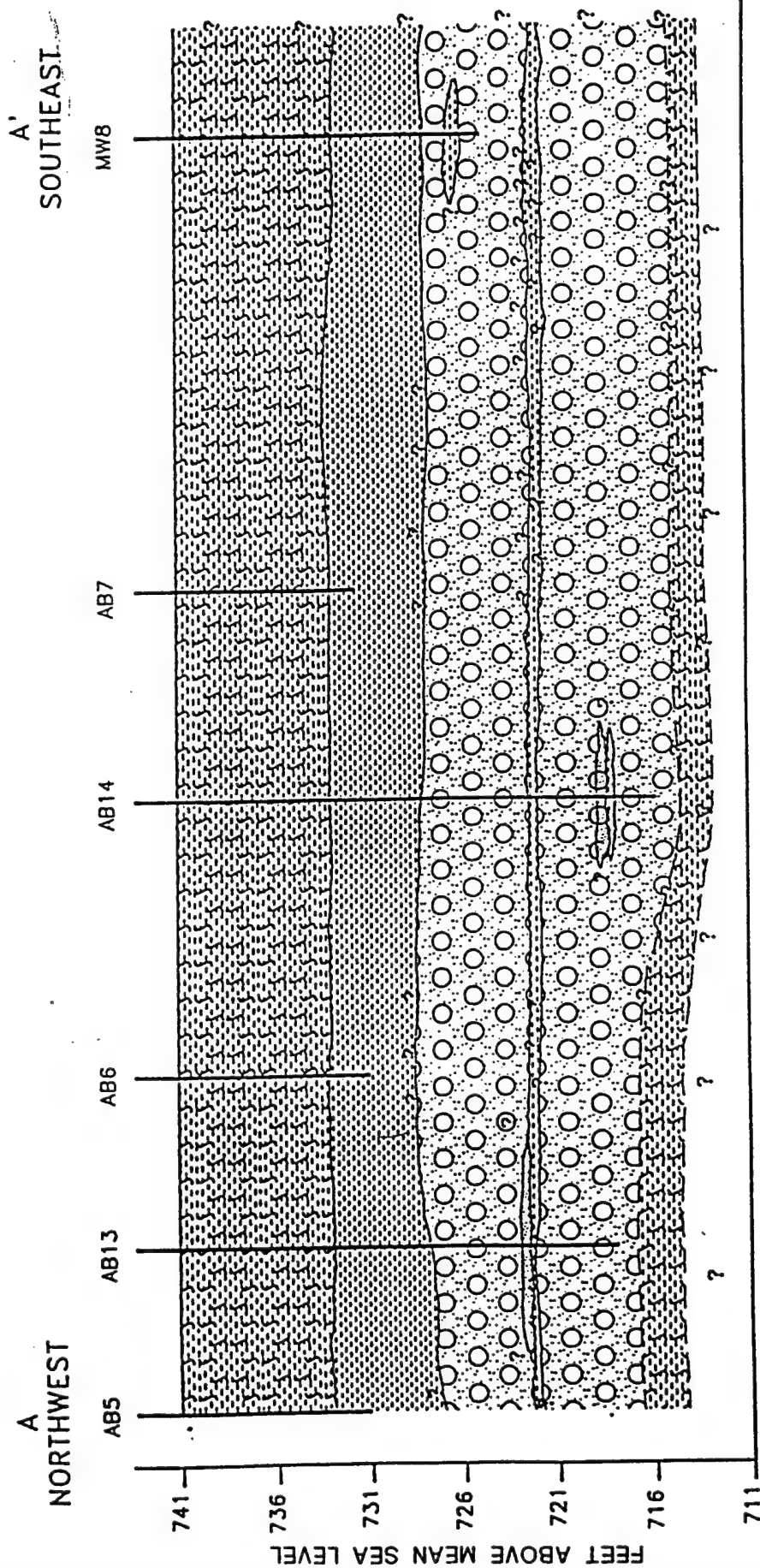


FIGURE 2.3

GENERALIZED GEOLOGIC CROSS SECTION A-A'

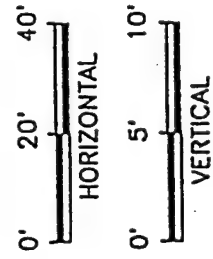
Site 1 (HWSA)

Intrinsic Remediation TS

Rickenbacker Air National Guard Base, Ohio



Denver, Colorado



LEGEND:

	GRAY, SILTY CLAY		BROWN, FINE SAND
	BROWN, SILTY CLAY		BROWN OR GRAY, SANDY GRAVEL

B
NORTHEAST

B'
SOUTHWEST

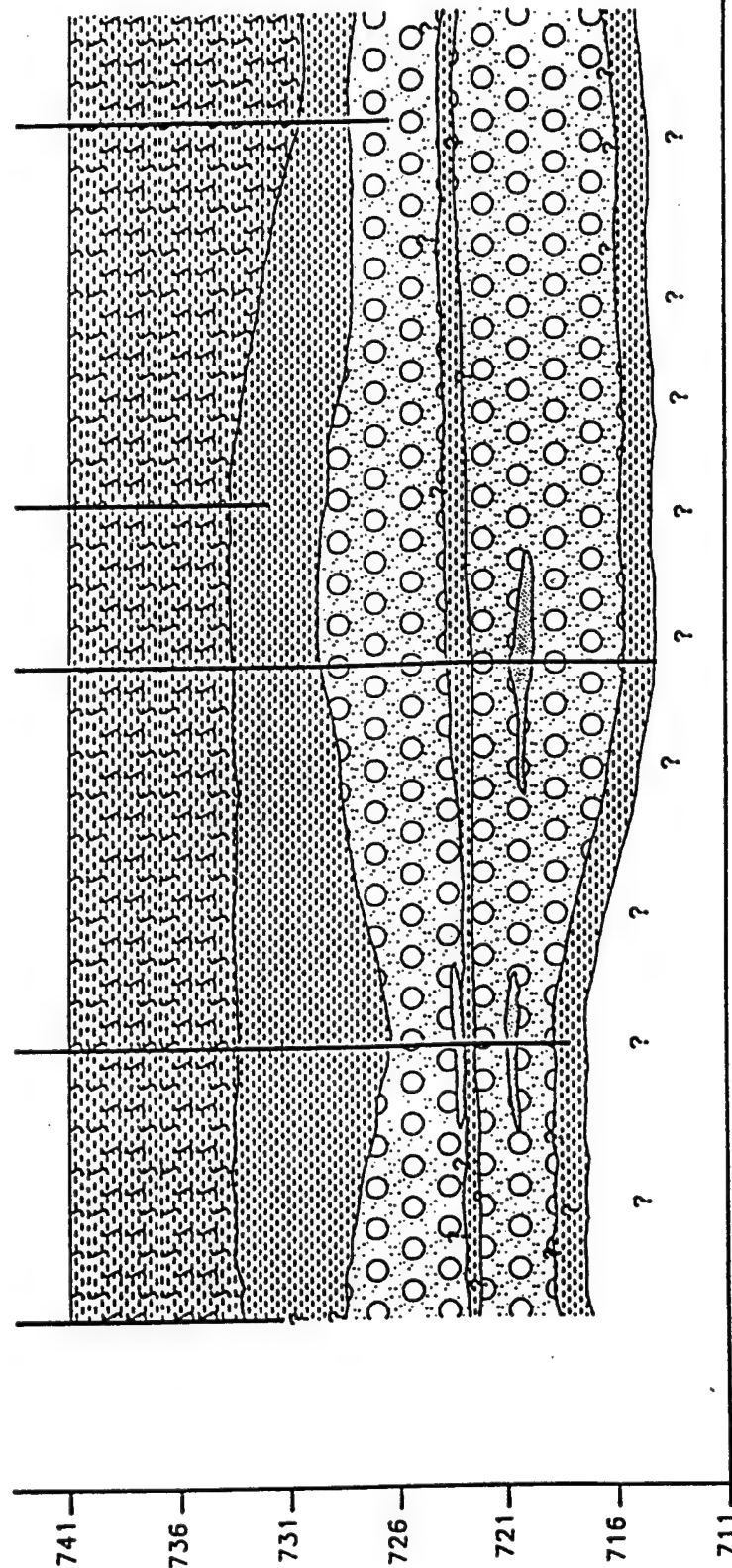
MW6

AB10

AB15





AB12

AB3



FEET ABOVE MEAN SEA LEVEL

LEGEND:

-  GRAY, SILTY CLAY
-  BROWN, FINE SAND W/INTERBEDDED FINE SANDS
-  BROWN, SILTY CLAY
-  BROWN OR GRAY, SANDY GRAVEL

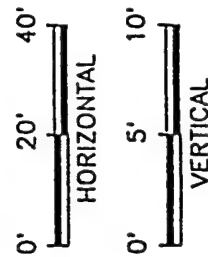


FIGURE 2.4

GENERALIZED GEOLOGIC
CROSS SECTION B-B'

Site 1 (HWSA)

Intrinsic Remediation TS

Rickenbacker Air National Guard Base, Ohio



Denver, Colorado

Source: ES, 1992a

M:\45025\DRAWINGS\95DN0132, 2/13/95 at 7:45

TABLE 2.1

SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS

SITE 1 (HWSA)

INTRINSIC REMEDIATION TS

RICKENBACKER ANGB, OHIO

Well ID	Completion Date	Well Material	Elevation		Top of Filter Pack		Top of Well Screen		Bottom of Well Screen		Bottom of Well	
			TOC ft msl a/	GS ft msl b/	Depth ft bgs c/	Elev ft msl	Depth ft bgs	Elev ft msl	Depth ft bgs	Elev ft msl	Depth ft bgs	Elev ft msl
MW-1	7/19/88	2" PVC	743.43	741.2		741.2	9.0	732.2	19.0	722.2	20.0	721.2
MW-2	7/29/88	2" PVC	743.25	741.0	38.0	703.0	5.0	736.0	15.0	726.0	15.0	726.0
MW-3	8/18/88	2" PVC	743.89	741.6	32.0	709.6	7.0	734.6	17.0	724.6	18.0	723.6
MW-4	1/29/90	2" PVC	745.01	NA ^{d/}	36.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-5	1/31/90	2" PVC	744.99	NA	36.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-6	1/30/90	2" PVC	744.99	NA	33.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-7	1/30/90	2" PVC	745.16	NA	36.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-8	1/30/90	2" PVC	743.74	NA	36.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-9	2/9/90	2" PVC	745.12	NA	36.0	NA	5.0	NA	15.0	NA	16.0	NA
MW-10	10/14/91	2" PVC	742.44	NA	6.0	NA	8.0	NA	18.0	NA	18.0	NA
MW-11	10/15/91	2" PVC	744.04	NA	5.5	NA	7.5	NA	17.5	NA	17.5	NA
MW-12	10/16/91	2" PVC	742.87	NA	6.0	NA	8.0	NA	18.0	NA	18.0	NA

Source: ES, 1989, 1992a, and 1992b

a/ Top of casing; feet above mean sea level

b/ Ground surface; feet above mean sea level

c/ Feet below ground surface

d/ Not available

The shallow surficial aquifer is at least 10 feet thick in the Site 1 area. Groundwater is present within the sands and gravels of the surficial aquifer at depths ranging from 8 to 17 feet bgs, and the elevation of groundwater surface ranges from 727 to 734 feet above msl. The shallow surficial aquifer exists under semiconfined conditions, as the water levels within the wells at Site 1 rise above the top of the sand and gravel unit. Groundwater levels in wells at Site 1 fluctuate as much as 6 feet seasonally. Highest groundwater level elevations were observed in October 1988, and the lowest elevations were recorded in April 1989. Table 2.2 presents a summary of groundwater level measurements. Based on historic groundwater elevation data, flow is expected to be to the south and southeast toward Walnut Creek (Figure 2.5). A slight rise in groundwater elevations was recorded in the vicinity of the USTs during February 1990. This rise was attributed to the accumulation of water within the fill material surrounding the tanks.

The horizontal hydraulic gradient in the vicinity of Site 1 is approximately 0.047 foot/foot (ft/ft). Rising head slug tests suggest the average hydraulic conductivity of the shallow surficial aquifer is about 2.35 feet per day (ft/day). Rising head slug test results are presented in Table B.1 in Appendix B. Assuming a porosity of 0.25, a horizontal hydraulic gradient of 0.047 ft/ft, and a hydraulic conductivity of 2.35 ft/day, the average groundwater velocity was calculated to be 0.44 ft/day (ES, 1989, 1992a, 1992b, and 1992c).

2.1.3 Soil Quality

During site investigation activities conducted by ES (1989, 1992a, 1992b, and 1992c), four primary areas of soil contamination were identified. The largest area is located adjacent to the building foundation in the grassy area that is in the center of Site 1. Contamination is estimated to extend south from the northwestern corner of the building foundation to an area southeast of the former location of the four 25,000-gallon USTs. The second contaminated area lies to the northwest of Building 560, and another area lies to the southeast of Building 560. The final contaminated area is located in the center of the drum storage area. Figure 2.6 presents the estimated extent of benzene, toluene, ethylbenzene, and xylenes (BTEX) contamination in the soil at Site 1.

A soil gas survey was conducted at nine points at Site 1 in July 1988, to determine the areal extent of soil contamination. BTEX contamination was identified at two soil gas survey locations: southeast of Building 560 at point 1SG-1 at 29.81 parts per million per volume (ppmv), and southeast of the abandoned separator pits at point 1SG-6 at 0.66 ppmv (Figure 2.6). Table B.2 in Appendix B presents a summary of soil gas survey results.

Soil samples were collected for laboratory analysis from surface soil investigations, shallow hand borings, and from the boreholes of the three monitoring wells installed during initial SI by conducted by ES (1989) (Section 2.1.2.2). A summary of laboratory analytical data from soil samples collected at Site 1 is presented in

TABLE 2.2
SUMMARY OF GROUND WATER LEVEL AND FREE PRODUCT MEASUREMENTS
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Sample Location	Sample Date	Easting	Northing	Datum Elevation ^{a/} (ft msl) ^{d/}	Datum Elevation ^{b/} (ft msl)	Depth to Water (ft TOC) ^{c/}	Depth to Product (ft TOC)	Product Thickness (feet)	Corr. Depth to Water ^{c/} (ft TOC)	Corr. GW Elevation (ft msl)
MW-1	9/16/88	NA ^{e/}	NA	743.60		10.40			10.40	733.20
	10/17/88	NA	NA	743.60		12.11			12.11	731.49
	11/17/88	NA	NA	743.60		10.72			10.72	732.88
	12/17/88	NA	NA	743.60		11.84			11.84	731.76
	1/20/89	NA	NA	743.60		10.30			10.30	733.30
	2/15/89	NA	NA	743.60		10.15			10.15	733.45
	3/15/89	NA	NA	743.60		9.98			9.98	733.62
	4/19/89	NA	NA	743.60		8.83			8.83	734.77
	10/17/91	NA	NA		743.43	14.78	14.73	0.05	14.74	728.69
MW-2	9/16/88	NA	NA	743.38		10.35			10.35	733.03
	10/17/88	NA	NA	743.38		12.00			12.00	731.38
	11/17/88	NA	NA	743.38		10.78			10.78	732.60
	12/17/88	NA	NA	743.38		11.75			11.75	731.63
	1/16/89	NA	NA	743.38		9.46			9.46	733.92
	2/15/89	NA	NA	743.38		10.10			10.10	733.28
	3/15/89	NA	NA	743.38		9.90			9.90	733.48
	4/19/89	NA	NA	743.38		9.30			9.30	734.08
	10/17/91	NA	NA		743.25	14.77			14.77	728.48
MW-3	9/16/88	NA	NA	744.09		10.50			10.50	733.59
	10/17/88	NA	NA	744.09		12.42			12.42	731.67
	11/17/88	NA	NA	744.09		10.82			10.82	733.27
	12/17/88	NA	NA	744.09		12.17			12.17	731.92
	1/20/89	NA	NA	744.09		10.21			10.21	733.88
	2/15/89	NA	NA	744.09		9.71			9.71	734.38
	3/15/89	NA	NA	744.09		9.73			9.73	734.36
	4/19/89	NA	NA	744.09		9.45			9.45	734.64
	10/17/91	NA	NA		743.89	15.43			15.43	728.46
MW-4	10/17/91	NA	NA		745.01	15.65			15.65	729.36
MW-5	10/17/91	NA	NA		744.99	16.49			16.49	728.50
MW-6	10/17/91	NA	NA		744.99	16.58			16.58	728.41
MW-7	10/17/91	NA	NA		745.16	17.25			17.25	727.91
MW-8	10/17/91	NA	NA		743.74	15.87			15.87	727.87
MW-9	10/17/91	NA	NA		745.12	17.03			17.03	728.09
MW-10	10/17/91	NA	NA		742.44	14.06			14.06	728.38
MW-11	10/17/91	NA	NA		744.04	15.83			15.83	728.21
MW-12	10/17/91	NA	NA		742.87	15.79			15.79	727.08

Source: ES, 1989, 1992a, 1992b, and 1993a

^{a/} Top of casing elevation

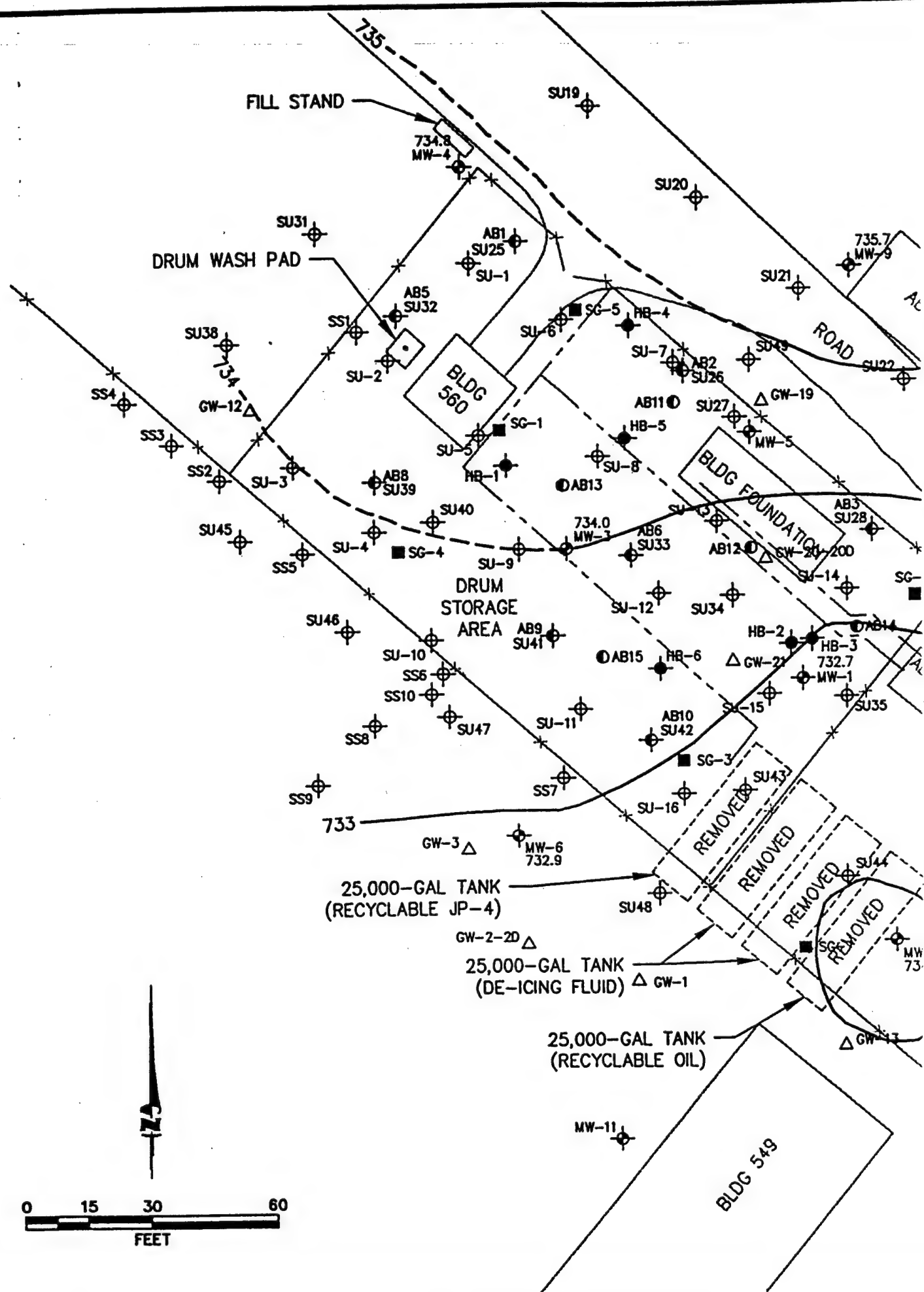
^{b/} Top of protective casing elevation

^{c/} Corrected depth to water = measured depth to water - (0.75 x product thickness)

^{d/} Feet above mean sea level

^{e/} Feet below top of specified casing elevation

^{f/} Not available



Source: ES, 1992b

M: \45025\DRAWINGS\95DN0122, 2/13/95 at 9:45

①

LEGEND



MONITORING WELL LOCATION



SURFACE SOIL SAMPLING LOCATION
(SU1 TO SU16, JULY 1988)
(SU19 TO SU49, JANUARY 1990)
(SS1 TO SS10, OCTOBER 1990)



HAND-AUGERED BORING LOCATION
(JULY 1988)



SHALLOW SOIL BOREHOLE
(JANUARY 1990)



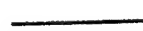
SHALLOW AND DEEP SOIL BOREHOLE
(JANUARY 1990)



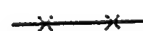
SOIL GAS SAMPLING LOCATION



GROUND WATER SCREENING LOCATION
(OCTOBER 1991)



ABANDONED FUEL LINE



FENCE



GROUND WATER FLOW
DIRECTION



LINE OF EQUAL GROUND WATER
ELEVATION (FEBRUARY 1990)
(feet above MSL)

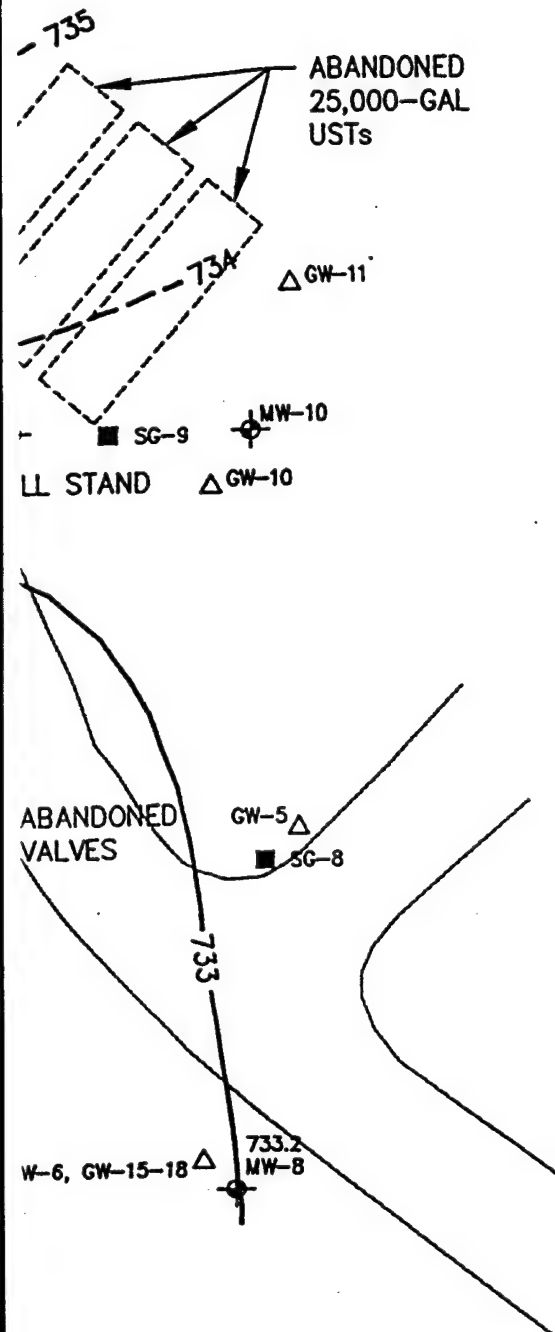


FIGURE 2.5

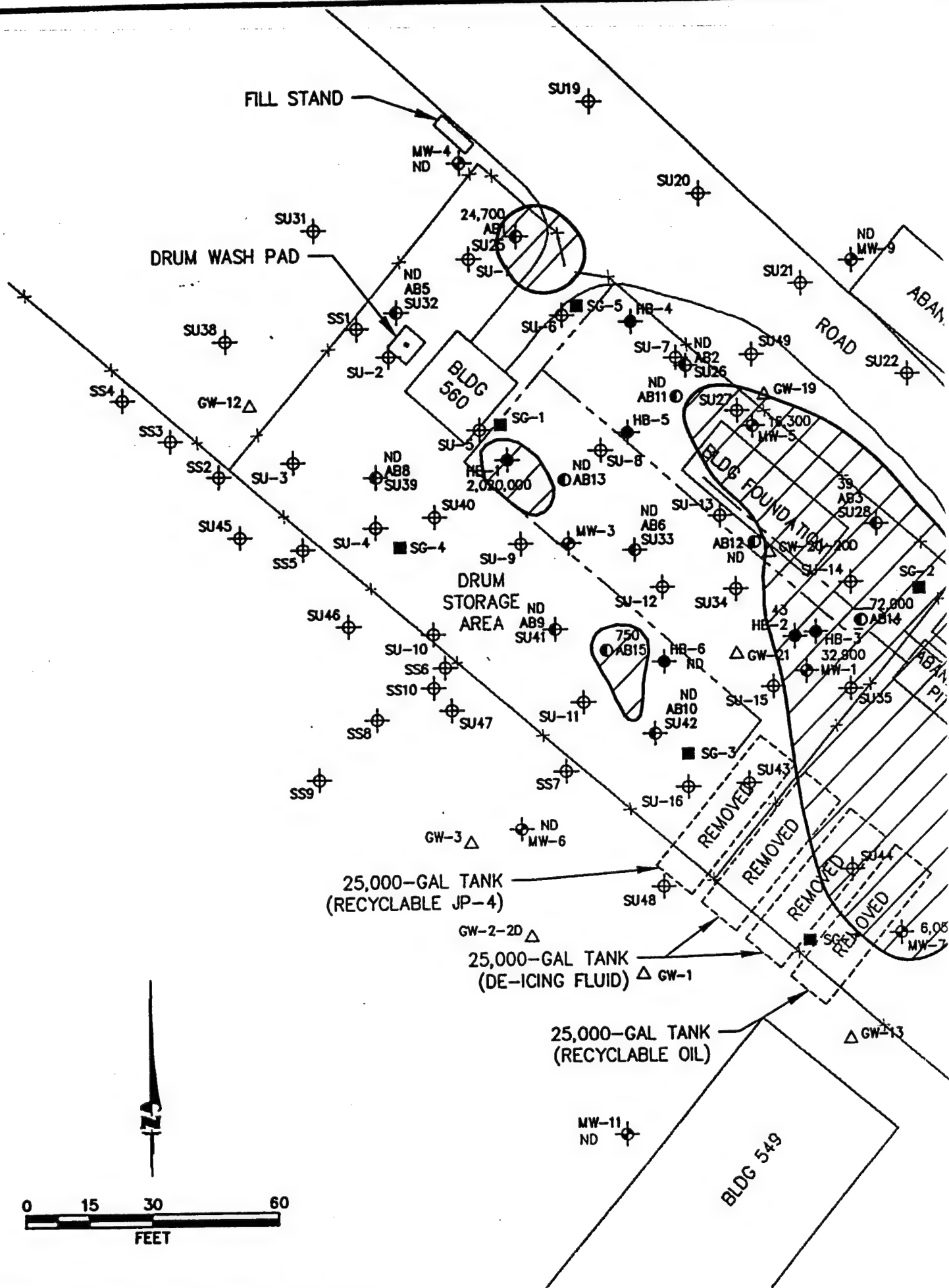
WATER TABLE ELEVATION MAP FEBRUARY 1990

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado



Source: ES, 1989, 1992a, 1992b and 1992c

M: \45025\DRAWINGS\95DN0122, 2/13/95 at 9:45

①

LEGEN

300,000

MONITOR
W/ TOT



SURFACE
(SU1 T
(SU19
(SSI T



HAND-A
(JULY



SHALLOW
W/ TOT



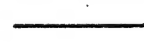
SHALLOW
(JANUA
W/ TOT



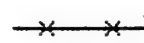
SOIL GAS



GROUND
(OCTOB



ABANDONED



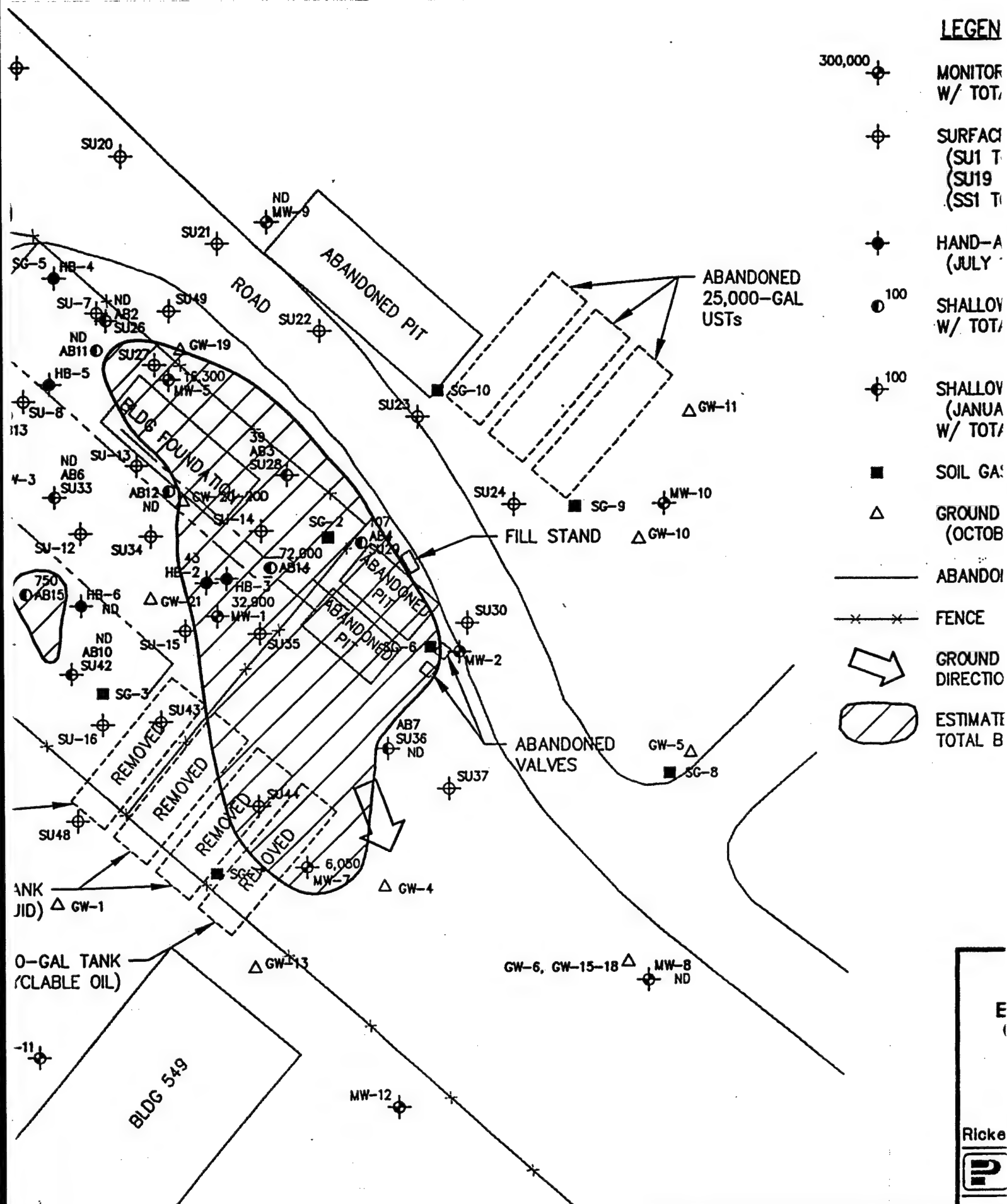
FENCE



GROUND
DIRECTIO



ESTIMATE
TOTAL B



LEGEND

300,000

MONITORING WELL LOCATION
W/ TOTAL BTEX CONCENTRATION IN $\mu\text{g/L}$



SURFACE SOIL SAMPLING LOCATION
(SU1 TO SU16, JULY 1988)
(SU19 TO SU49, JANUARY 1988)
(SS1 TO SS10, OCTOBER 1990)



HAND-AUGERED BORING LOCATION
(JULY 1988)



SHALLOW SOIL BOREHOLE (JANUARY 1990)
W/ TOTAL BTEX CONCENTRATION IN $\mu\text{g/L}$



SHALLOW AND DEEP SOIL BOREHOLE
(JANUARY 1990)
W/ TOTAL BTEX CONCENTRATION IN $\mu\text{g/L}$



SOIL GAS SAMPLING LOCATION



GROUND WATER SCREENING LOCATION
(OCTOBER 1991)



ABANDONED FUEL LINE



FENCE



GROUND WATER FLOW
DIRECTION



ESTIMATED AREAL EXTENT OF SOIL
TOTAL BTEX CONTAMINATION

ABANDONED
25,000-GAL
USTs

△ GW-11

■ SG-9

○ MW-10

△ GW-10

STAND

GW-5

■ SG-8

ABANDONED
VALVES

1-6, GW-15-18

○ MW-8
ND

FIGURE 2.6

ESTIMATED AREAL EXTENT OF BTEX CONTAMINATION IN SOIL

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Table 2.3. Laboratory analyses indicate that the greatest concentrations of contaminants were present in soils in the grassy area southeast of Building 560. A total BTEX concentration of 2,020,000 micrograms per kilogram ($\mu\text{g/kg}$), a naphthalene concentration of 1,600 $\mu\text{g/kg}$, and a 2-methylnaphthalene concentration of 2,800 $\mu\text{g/kg}$ were obtained in the 2.6- to 3.9-foot bgs sample in hand boring HB-1. Of the BTEX contaminants, only xylene and ethylbenzene were detected in HB-1 (Table 2.3). A total BTEX concentration of 32,900 $\mu\text{g/kg}$, a naphthalene concentration of 630 $\mu\text{g/kg}$, and a 2-methylnaphthalene concentration of 1,200 $\mu\text{g/kg}$ were detected in soil samples associated with the boring of monitoring well MW-1. Samples from hand boring HB-2 also contained significant naphthalene and 2-methylnaphthalene contamination (5,400 $\mu\text{g/kg}$ and 23,000 $\mu\text{g/kg}$, respectively). Soil samples from the other two monitoring wells and the other four hand soil boring showed no evidence of contamination. The 16 surface soil samples either were not analyzed or showed no evidence of volatile or aromatic hydrocarbon contamination (ES, 1989).

Soil analytical results were also reported for field sampling associated with the pre-closure investigation performed by ES (1992a). Soil analytical results are available for surface soil samples, shallow soil borings, deep soil borings, and borings performed during the installation of monitoring wells MW-4 to MW-9 (Section 2.1.2.2). Table 2.3 also summarizes these data. The greatest total BTEX concentrations were identified in soil samples from monitoring well boreholes MW-5 and MW-7. Monitoring well MW-5, located east of Building 560 adjacent to the building foundation (Figure 2.6), contained total BTEX concentrations of 16,300 $\mu\text{g/kg}$ at a depth of 13 to 15 feet bgs. A sample from 8 to 10 feet bgs at monitoring well MW-7, located southeast of the USTs, had a total BTEX concentration of 6,080 $\mu\text{g/kg}$. In the shallow soil samples, contamination was identified in samples from 8 to 10 feet bgs at locations AB1 and AB3. At shallow soil sample location AB1, located north of Building 560, the total BTEX concentration was 24,700 $\mu\text{g/kg}$. The soil sample collected at location AB3, positioned near the building foundation, contained a total BTEX concentration of 39 $\mu\text{g/kg}$. Elevated total BTEX concentrations were also detected in deep soil borings AB14 and AB15. Deep soil boring AB14, located southeast of the building foundation, had a total BTEX concentration of 72,000 $\mu\text{g/kg}$, and location AB15, near the center of the grassy area, contained 250 $\mu\text{g/kg}$ of BTEX compounds.

As part of the field effort to identify the free-phase hydrocarbons at Site 1 (ES, 1992c), excavations were installed in around the USTs and the abandoned separator pits. Soil sample headspace readings indicated elevated VOC concentrations in the abandoned pit northeast of the building foundation and in each of the four soil stockpiles created during excavation activities. Table B.3 in Appendix B presents a summary of VOC headspace data. Volatile hydrocarbon contamination was identified in the abandoned pit to the northeast of the building foundation (39 $\mu\text{g/kg}$) by laboratory analysis (ES, 1992c).

Soil samples were also collected for laboratory analysis during installation of monitoring wells MW-10 through MW-12 (ES, 1992a). Analytical laboratory data

TABLE 2.3

SUMMARY OF SOIL ANALYTICAL DATA
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Sample Location	Sample Date	Sample Depth (feet bgs)	Benzene ^{a/} (µg/kg)	Toluene ^{a/} (µg/kg)	Ethylbenzene ^{a/} (µg/kg)	m&p-xylene ^{a/} (µg/kg)	o-Xylene ^{a/} (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Naphthalene ^{b/} (µg/kg)	2-Methylnaphthalene ^{b/} (µg/kg)
HB1-SS1	6/14/88	0-1.3	NA ^{a/}	ND ^{a/}	ND	NA	440,000	440,000	440,000	ND	1,100
HB1-SS2	6/14/88	1.3-2.6	NA	ND	ND	NA	300,000	300,000	300,000	390	960
HB1-SS3	6/14/88	2.6-3.9	NA	ND	120,000	NA	1,900,000	1,900,000	2,020,000	1,600	2,800
HB2+3-SS1	6/14/88	0-1.3	NA	ND	ND	NA	ND	0	ND	870	1,900
HB2-SS2	6/14/88	1.3-2.6	NA	ND	ND	NA	43	43	43	5,400	23,000
HB2-SS3	6/14/88	2.6-3.9	NA	ND	ND	NA	ND	ND	ND	570	2,800
HB4-SS1	7/6/88	0-1.3	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB4-SS2	7/6/88	1.3-2.6	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB4-SS3	7/6/88	2.6-3.9	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB5-SS1	7/6/88	0-1.3	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB6-SS1	7/6/88	0-1.3	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB6-SS2	7/6/88	1.3-2.6	NA	ND	ND	NA	ND	ND	ND	ND	ND
HB6-SS3	7/6/88	2.6-3.9	NA	ND	ND	NA	ND	ND	ND	ND	ND
AB1-SS1	1/22/90	3-5	6 U ^{a/}	5 U ^{a/}	6 U	6 U	6 U	12 U	29U	NA	NA
AB1-SS2	1/22/90	8-10	1200 U ^{a/}	710 U	6,700	6,000	12,000	18,000	24,700	NA	NA
AB2-SS1	1/22/90	3-5	1 J	6 U	6 U	6 U	6 U	12U	1J	NA	NA
AB2-SS2	1/22/90	8-10	6 U	5 U ^{a/}	6 U	6 U	6 U	12U	29U	NA	NA
AB3-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	42U	NA	NA
AB3-SS2	1/23/90	8-10	39	6 U	6 U	6 U	6 U	12U	39	NA	NA
AB4-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB4-SS2	1/23/90	8-10	6 U	6 U	20	36	51	87	107	NA	NA
AB5-SS1	1/22/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB5-SS2	1/22/90	8-10	6 U	5 U ^{a/}	6 U	6 U	6 U	12U	29U	NA	NA
AB6-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB6-SS2	1/23/90	8-10	1 J	6 U	6 U	6 U	6 U	12U	1J	NA	NA
AB7-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB7-SS2	1/23/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB8-SS1	1/22/90	3-5	6 U	5 U ^{a/}	6 U	6 U	6 U	12U	29U	NA	NA
AB8-SS2	1/22/90	8-10	6 U	5 U ^{a/}	6 U	6 U	6 U	12U	29U	NA	NA
AB9-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB9-SS2	1/23/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB10-SS1	1/23/90	3-5	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB10-SS2	1/23/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB11-SS4	1/26/90	15-17	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB11-SS7	1/26/90	21-23	6 U	2 J	6 U	6 U	6 U	12U	2J	NA	NA
AB12-SS3	1/24/90	13-15	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB12-SS7	1/24/90	21-13	6 J	6 J	6 J	6 J	6 J	12J	30J	NA	NA
AB13-SS5	1/24/90	17-19	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
AB13-SS7	1/24/90	21-23	5 U	5 U	5 U	5 U	5 U	10U	25U	NA	NA
AB14-SS2	1/25/90	8-10	15,000	679 U	15,000	15,000	27,000	42,000	72,000	NA	NA
AB14-SS7	1/25/90	21-23	6	6 U	6 U	6 U	6 U	NA	30U	NA	NA
AB15-SS3	1/25/90	13-15	26 U	26 U	250	26 U	26 U	52U	250	NA	NA
AB15-SS8	1/25/90	25-27	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
SU28	6/14/88	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
SU41	6/14/88	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
SU42	6/14/88	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
SS9	10/16/91	NA	ND	ND	ND	NA	NA	NA	ND	NA	NA
SS10	10/16/91	NA	ND	ND	ND	NA	NA	NA	ND	NA	NA
MW1-SS1	7/20/88	NA	ND	ND	1,700	NA	1,600	1,600	3,300	ND	ND
MW1-SS2	7/20/88	NA	1,900	ND	11,000	NA	20,000	20,000	32,900	630	1,200
MW2-SS1	7/29/88	NA	ND	ND	ND	NA	ND	ND	ND	ND	ND
MW2-SS2	7/29/88	NA	ND	NA	ND	NA	ND	ND	ND	ND	ND
MW2-SS3	7/29/88	NA	ND	NA	ND	NA	ND	ND	ND	ND	ND
MW3-SS1	8/10/88	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
MW3-SS2	8/10/88	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
MW4-SS2	1/29/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW4-SS3	1/29/90	13-15	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW5-SS2	1/31/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW5-SS3	1/31/90	13-15	694 U	694 U	7,400	1,900	7,000	8,900	16,300	NA	NA

TABLE 2.3 (Continued)

SUMMARY OF SOIL ANALYTICAL DATA
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Sample Location	Sample Date	Sample Depth (feet bgs)	Benzene ^{a/} (µg/kg)	Toluene ^{a/} (µg/kg)	Ethylbenzene ^{a/} (µg/kg)	m&p-xylene ^{a/} (µg/kg)	o-Xylene ^{a/} (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Naphthalene ^{b/} (µg/kg)	2-Methylnaphthalene ^{b/} (µg/kg)
MW6-SS2	1/30/90	8-10	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW6-SS3	1/30/90	11-13	6 U	1J	6 U	6 U	6 U	12U	1J	NA	NA
MW7-SS2	1/30/90	8-10	2,100	682 U	980	1,800	1,200	3,000	6,080	NA	NA
MW7-SS3	1/30/90	11-13	140	4 J	6 U	6 U	6 U	12U	140	NA	NA
MW8-SS2	1/31/90	9-11	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW8-SS3	1/31/90	13-15	2 J	6 U	6 U	6 U	6 U	12U	2J	NA	NA
MW9-SS2	2/09/90	9-11	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW9-SS3	2/09/90	13-15	6 U	6 U	6 U	6 U	6 U	12U	30U	NA	NA
MW10	10/14/91	8-10	12 U	12 U	12 U	NA	NA	12 U	48U	NA	NA
MW10	10/14/91	13-15	13 U	13 U	13 U	NA	NA	13 U	52U	NA	NA
MW11	10/15/91	8-10	11U	11U	11U	NA	NA	11U	44U	NA	NA
MW11	10/15/91	13-15	12 U	12 U	12 U	NA	NA	12 U	48U	NA	NA
MW12	10/15/91	8-10	11 U	11 U	11 U	NA	NA	11 U	44U	NA	NA
MW12	10/15/91	13-15	11U	11U	11U	NA	NA	11U	40U	NA	NA
NE PIT	7/6/90		1J		9	29	<5	<34	38	NA	NA

Source: ES, 1989,1992a,1992b, and 1992c

^{a/} Sample was analyzed by using method SW8020 in 1988 or sample was analyzed by using method CLP/8240 in 1990 and 1991

^{b/} Sample was analyzed by using method Sw8270 in 1988 or sample was analyzed by using method CLP/8240 in 1990 and 1991

^{c/} µg/kg = micrograms per kilogram

^{d/} NA = not analyzed

^{e/} ND = not detected

^{f/} U = the compound was analyzed for, but not detected

^{g/} J = the value reported is an estimated concentration

from the soil samples collected at MW-10, MW-11, and MW-12 indicated no contamination was present at those locations (Figure 2.6). VOC headspace analysis was conducted for surface soil samples SS-1 through SS-10 (Section 2.1.2.2). Elevated VOC readings were found in all of these surface soil samples except SS-1, SS-2, and SS-7 (Table B.3). Laboratory samples acquired from surface soil samples SS-9 and SS-10 did not contain BTEX contamination. Surface soil samples SS-1 through SS-8 were not analyzed for BTEX compounds.

2.1.4 Ground Water Quality and Chemistry

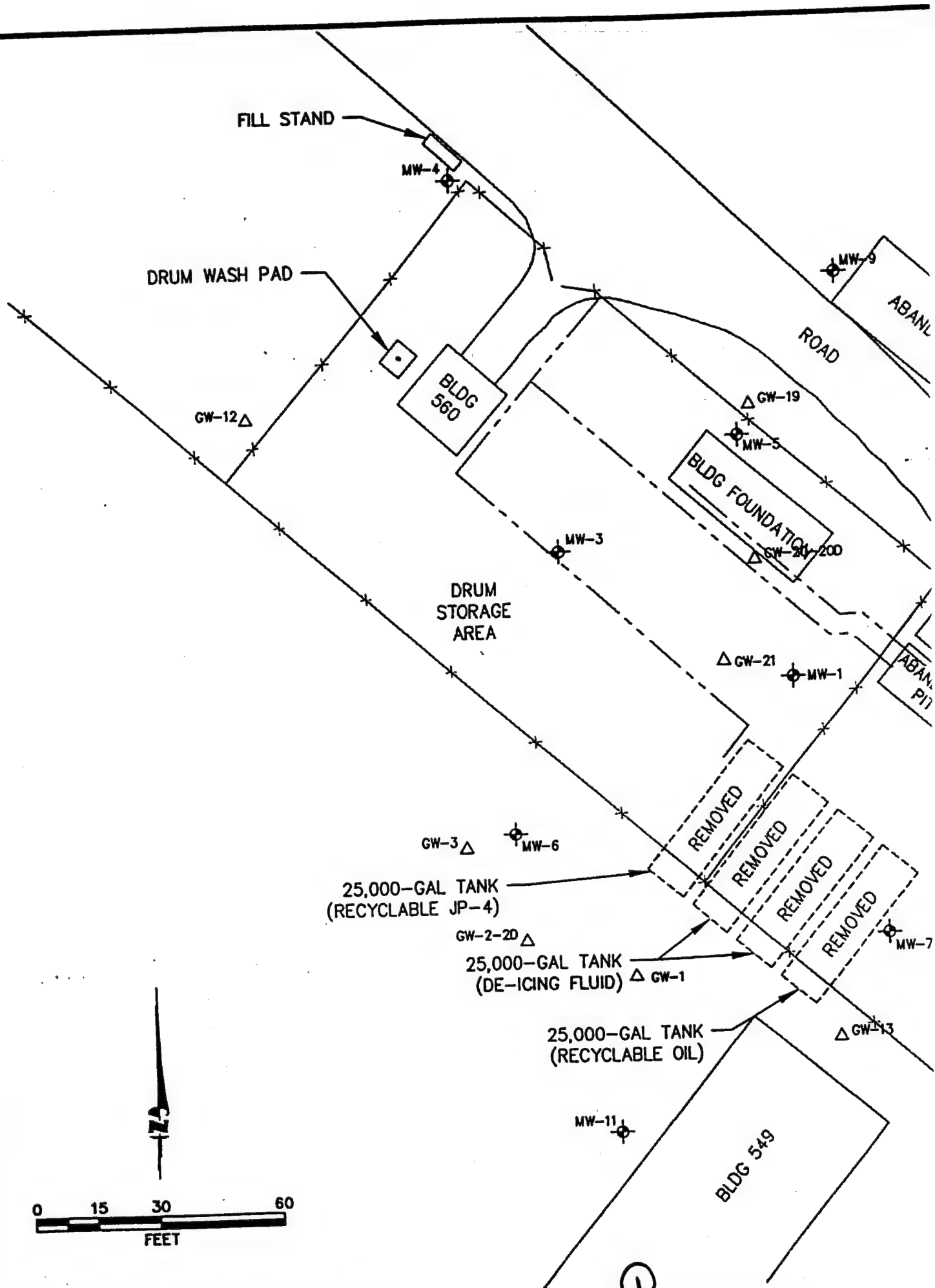
Twelve monitoring wells (MW-1 through MW-12) have been installed in the vicinity of Site 1 (Figure 2.7). Petroleum hydrocarbon compounds have been detected in wells MW-1 and MW-7, while halogenated organic compounds have been detected in wells MW-3 and MW-6. In addition, free-phase hydrocarbons have been detected in wells MW-1 and MW-5 (ES, 1992a and 1992b). Previous analytical results for monitoring well samples are summarized in Table 2.4. The estimated extent of dissolved BTEX contamination in 1990 is indicated on Figure 2.8.

Detected total BTEX concentrations were greatest at MW-1, with the 1990 sample from that well containing 796 micrograms per liter ($\mu\text{g/L}$) of total BTEX, including 60 $\mu\text{g/L}$ of benzene. This well was not sampled in 1991 due to the presence of free-phase hydrocarbons. At MW-7, the total BTEX concentration was 431 $\mu\text{g/L}$ in 1990 and 119 $\mu\text{g/L}$ in 1991. In 1990, the benzene concentration in the MW-7 sample was 200 $\mu\text{g/L}$, while in 1991 it was 19 $\mu\text{g/L}$. Well MW-5 has apparently never been sampled because it has always contained free product. Halogenated compounds detected at MW-3 and MW-6 include trichloroethene (TCE) and 1,2-dichloroethene (DCE). Samples collected from MW-3 in 1990, and 1991 contained TCE at concentrations of 7 and 8 $\mu\text{g/L}$, respectively. Samples collected from MW-6 at the same times contained both TCE and 1,2-DCE. In 1990, the TCE concentration at MW-6 was 78 $\mu\text{g/L}$, and the DCE concentration was 8 $\mu\text{g/L}$. In 1991, the TCE and DCE concentrations at MW-6 were 2,000 and 190 $\mu\text{g/L}$, respectively.

Groundwater screening samples were collected from several locations (using a Geoprobe[®] apparatus and a field gas chromatograph) in October 1991. These results generally confirm that previous sampling results indicated the full extent of BTEX and halogenated organic compound contamination. The results of this survey are presented in Table B.4.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL




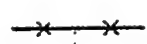

A conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of developing a site conceptual model is to provide an understanding of the mechanism for contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration

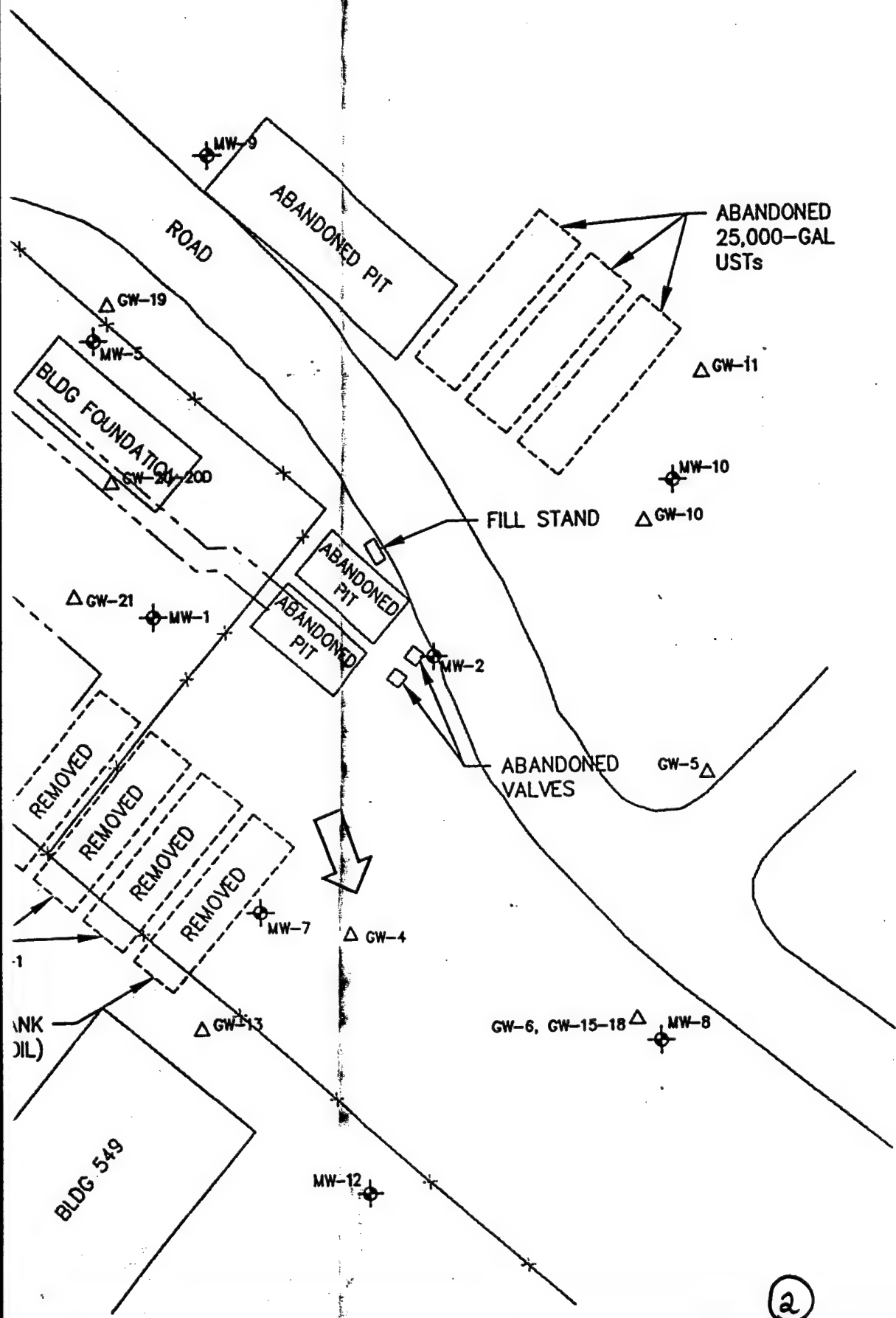


Source: ES, 1989, 1992a, 1992b and 1992c

V:\45025\DRAWINGS\95DN0122, 2/13/95 at 10:15

LEGEND

-  MONITORING
-  GROUND WAT
-  ABANDONED
-  FENCE
-  GROUND WAT DIRECTION








MONIT
SCREE

Intrir
Rickenbacker

 **PARSI
ENGINEERING**

D

LEGEND

-  MONITORING WELL LOCATION
-  GROUND WATER SCREENING LOCATION
-  ABANDONED FUEL LINE
-  FENCE
-  GROUND WATER FLOW DIRECTION

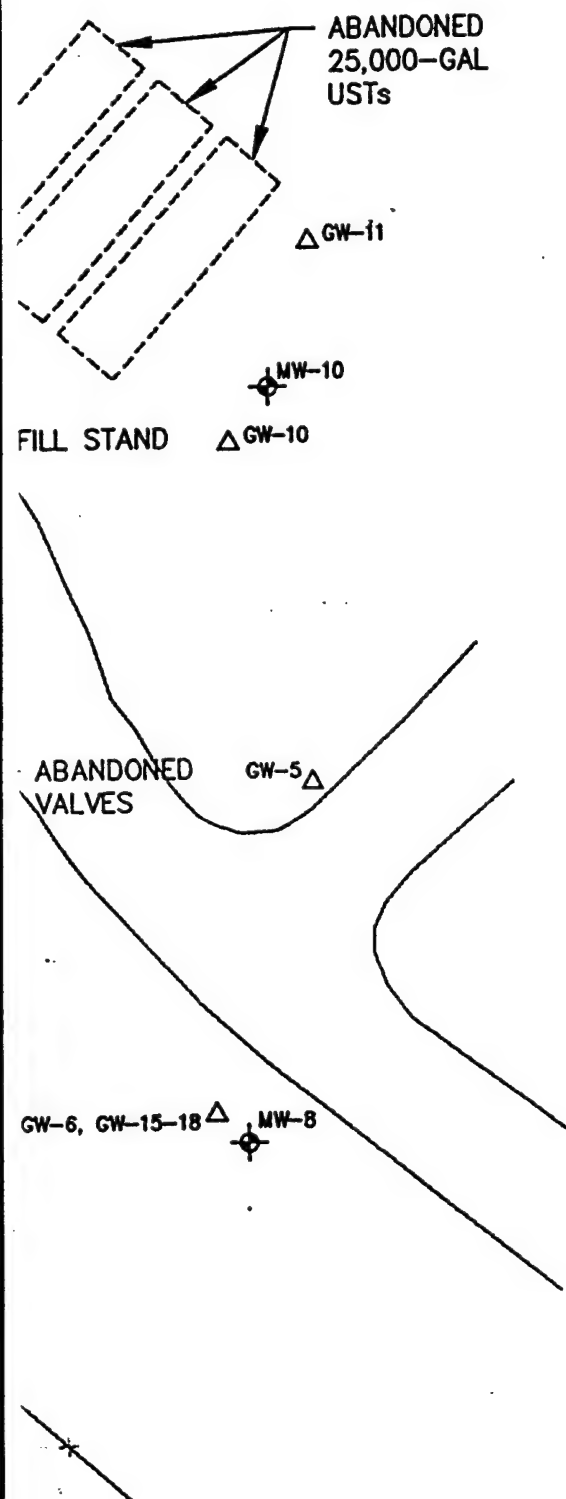


FIGURE 2.7

MONITORING WELL AND SCREENING LOCATIONS

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio

 **PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

TABLE 2.4

SUMMARY OF GROUND WATER ANALYTICAL DATA

SITE 1 (HWSA)

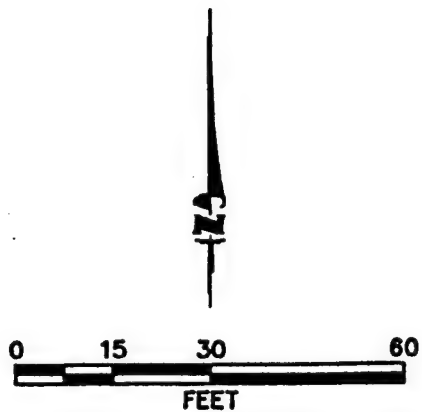
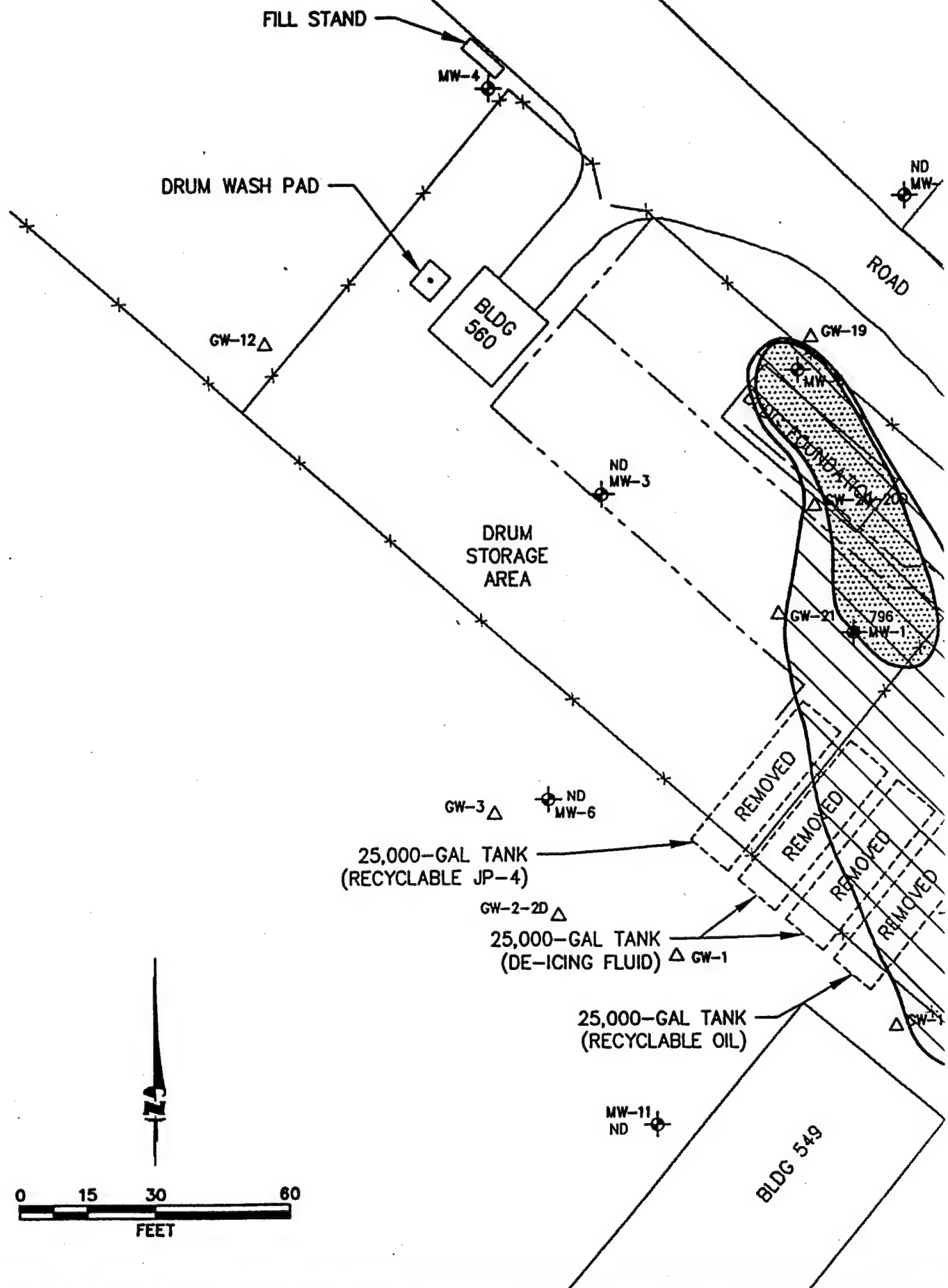
INTRINSIC REMEDIATION TS

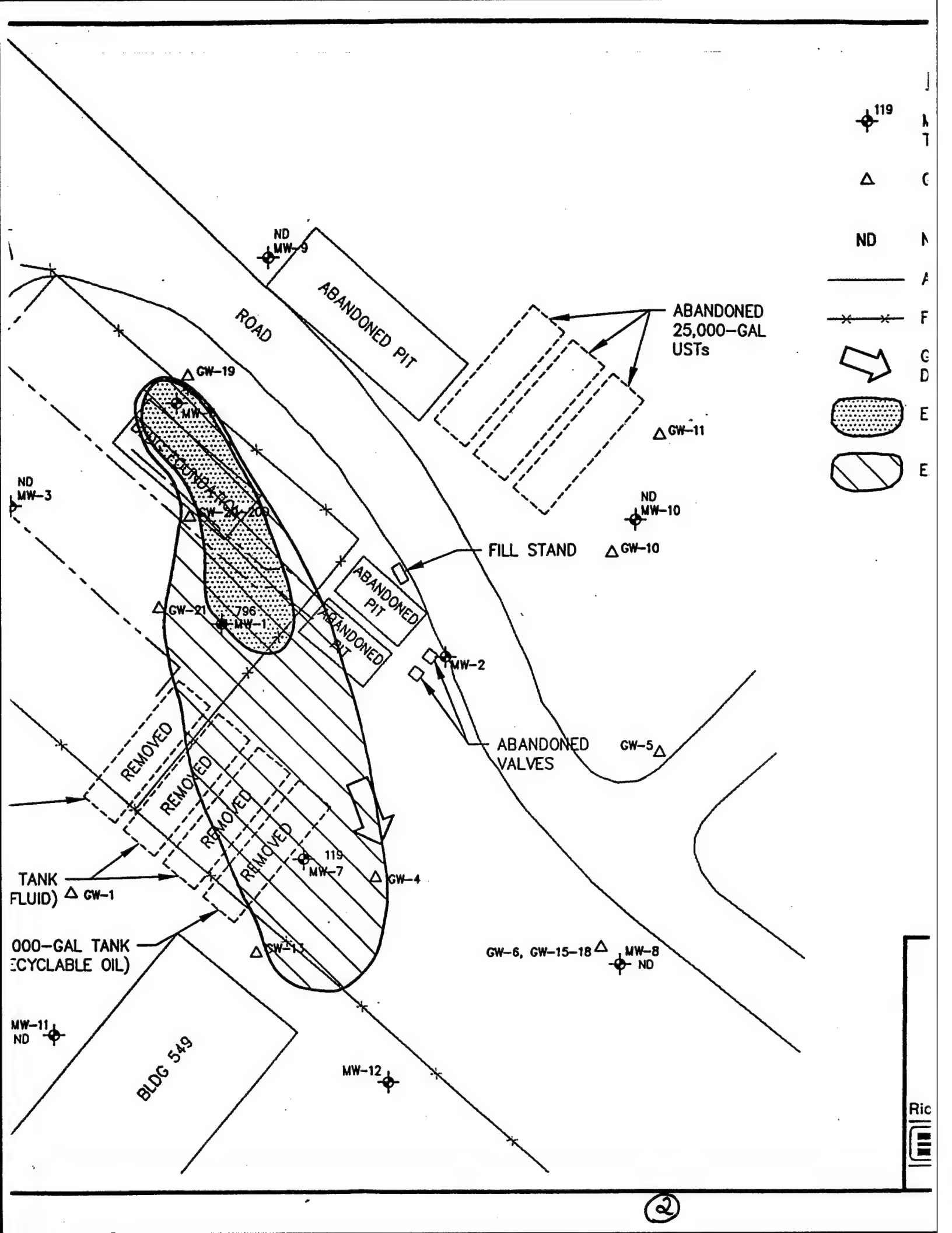
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Analyte	Sample Location																					
	MW1 1988	MW1 1990	MW2 1988	MW2 1990	MW2 1991	MW3 1988	MW3 1990	MW3 1991	MW4 1990	MW4 1991	MW6 1990	MW6 1991	MW7 1990	MW7 1991	MW8 1990	MW8 1991	MW9 1990	MW9 1991	MW10 1991	MW11 1991	MW12 1991	
Aromatic Volatile Organics																						
(µg/L) e/																						
Benzene	94	60D ^a	ND	5U	10U	ND	5U	10U	5U	10U	5U	100U	200	19	5U	10U	5U	10U	10U	10U	10U	
Toluene	ND ^d	5U ^{b/}	ND	5U	10U	ND	5U	10U	5U	10U	5U	100U	50U	2J ^{c/}	5U	10U	5U	10U	10U	10U	10U	
Ethylbenzene	ND	110	ND	5U	10U	ND	5U	10U	5U	10U	5U	100U	90	62	5U	10U	5U	10U	10U	10U	10U	
m/p-Xylenes	35		5U			ND	5U		5U		5U		21J		5U		5U					
o-Xylenes	20	86	ND	5U		ND	5U		5U		5U		70		5U		5U					
Xylenes					10U			10U		10U		100U		36		10U		10U		10U	10U	
Total BTEX	114	796	ND	25U	40U	ND	25U	40U	25U	40U	25U	400U	431	119	25U	40U	25U	40U	40U	40U	40U	
Petroleum Hydrocarbons																						
(µg/L) f/																						
Naphthalene	ND	10U	ND	10U	10U	ND	10J	ND	10U	10U	10U	10U	10U	6J	10U	ND	10U	ND	10U	10U	10U	
Fluorene	ND	10U	ND	10U	10U	ND	10J	ND	10U	10U	10U	10U	10U	10U	10U	ND	10U	ND	10U	10U	10U	
Phenanthrene	ND	10U	ND	10U	10U	ND	10J	ND	10U	10U	10U	10U	10U	10U	10U	ND	10U	ND	10U	10U	10U	
Anthracene	ND	10U	ND	10U	10U	ND	10J	ND	10U	10U	10U	10U	10U	10U	10U	ND	10U	ND	10U	10U	10U	
Halogenated Organics																						
(µg/L) f/																						
Vinyl Chloride	ND	10U	ND	10U	10U	ND	10U	10U	10U	10U	10U	100U	100U	17	10U	10U	10U	10U	10U	10U	10U	
1,2-Dichloroethene (total)	ND	5U	ND	5U	10U	ND	5U	10U	5U	10U	8	190	50U	10U	5U	10U	5U	10U	10U	10U	10U	
Trichloroethene	ND	5U	ND	5U	10U	ND	7	8J	5U	10U	78	2000	50U	10U	5U	10U	5U	10U	10U	10U	10U	
Tetrachloroethene	ND	5U	ND	5U	10U	ND	5U	10U	5U	10U	5U	100U	50U	10U	5U	10U	5U	10U	10U	10U	10U	

Source: ES, 1989, 1992a, 1992b, 1992c

^{a/} Result is calculated from a greater dilution than the primary analysis^{b/} Compound was analyzed for, but not detected^{c/} Reported value is an estimated concentration^{d/} Not detected^{e/} Sample is analyzed by using method SW8010/8020 in 1988 or using method CLP/8240 in 1990 and 1991^{f/} Sample is analyzed by using method SW8270 in 1988 or by using method CLP/8240 in 1990 and 1991





LEGEND



MONITORING WELL LOCATION WITH
TOTAL BTEX CONCENTRATION IN $\mu\text{g/L}$



GROUND WATER SCREENING LOCATION
(OCTOBER 1990)

ND

NOT DETECTED



ABANDONED FUEL LINE



FENCE



GROUND WATER FLOW
DIRECTION



EXTENT OF FREE PRODUCT



EXTENT OF BTEX CONTAMINATION

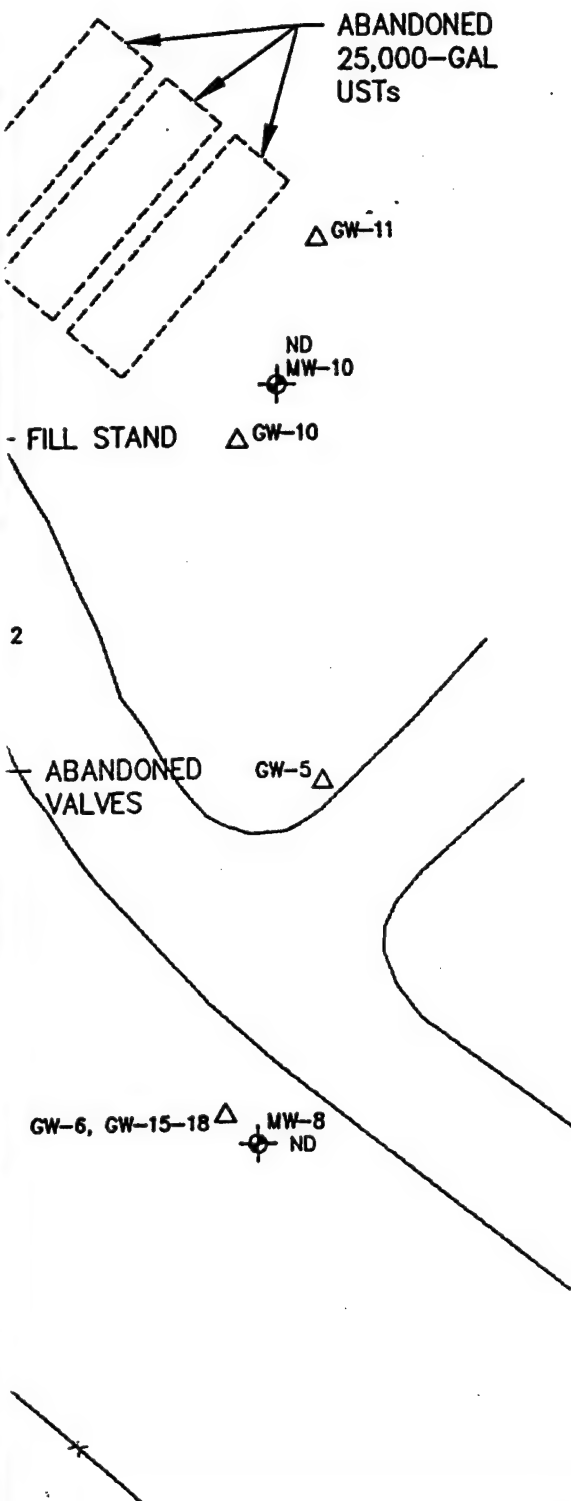


FIGURE 2.8

**ESTIMATED EXTENT OF
BTEX CONTAMINATION IN
GROUND WATER - 1990**

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

pathways. The model to be developed provides a foundation for identifying data gaps and formulating decisions regarding additional data collection activities and potential remedial actions. The conceptual model for Site 1 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling hydrocarbon degradation using the Bioplume II model.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphic data,
 - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors; and
- Determining additional data requirements.

2.2.1 Intrinsic Remediation and the Bioplume II Model

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any exposure pathway for human or ecological receptors is complete. The Bioplume II model has proved useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. The Bioplume II model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the potential migration pathways to human and ecological receptors. Quantitative fate and transport analyses can be used to determine what level and extent of remediation is required.

An important consideration in determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment and what type of remedial alternative will be most cost effective in eliminating or abating these threats is an accurate estimate of the potential for natural biodegradation of BTEX compounds in the groundwater. Over the past 2 decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons via aerobic and anaerobic pathways (Lee *et al.*, 1988). This process occurs naturally when sufficient oxygen and other electron acceptors are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen or other electron acceptors rather than by the lack of nutrients such as nitrogen or phosphorus. The supply of oxygen to unsaturated soil is constantly renewed by the vertical diffusion from the atmosphere. The supply of oxygen to a shallow, fuel-contaminated aquifer is

constantly renewed by the influx of electron acceptor-rich upgradient flow and the vertical diffusion of oxygen from the unsaturated soil zone into the groundwater (Borden and Bedient, 1986). The rate of natural biodegradation in shallow aquifers is largely dependent upon the rate at which electron acceptors enter the contaminated media.

2.2.2 Biodegradation of Dissolved BTEX Contamination

The Bioplume II model is a well-documented and widely accepted numerical model available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. The positive effect of these processes on reducing the actual mass of fuel-related contamination dissolved in groundwater has been termed intrinsic remediation. The advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive and allows continuing use of infrastructure during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies.

To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, in preparation). The first is a documented loss of contaminants at the field scale. Dissolved concentrations of biologically-recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters such as groundwater seepage velocity and dilution to demonstrate that a reduction in the total contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, the Bioplume II computer model can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of the process of natural attenuation.

The Bioplume II model is based upon the USGS two-dimensional (2-D) solute transport model, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superimposition at every particle move to simulate biological reactions between fuel products and oxygen. If appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

2.2.3 Biodegradation of Dissolved Chlorinated Solvent Contamination

Biodegradation of chlorinated organic compounds in the natural environment can occur through cometabolism under either aerobic or anaerobic conditions. Analytical results from groundwater samples collected from Site 1 indicate the presence of dissolved chlorinated compounds in the form of TCE and 1,2-DCE. Cometabolism of TCE can occur by the production of enzymes or cofactors produced during the transformation of other primary organic substrates such as BTEX. The cometabolic processes usually only result in partial transformation of the chlorinated organic compound into an intermediate product. Anaerobic reduction of TCE by dechlorination produces either cis- or trans-DCE, both of which can be further transformed to vinyl chloride. Vinyl chloride may subsequently be reduced to ethylene or carbon dioxide. Reaction rates of cometabolism appear to be influenced by the reduction-oxidation conditions at a site. Dechlorination tends to proceed more rapidly in reducing conditions than under oxidizing conditions. Therefore, TCE degradation is likely to be kinetically favored in reducing environments where BTEX compounds are undergoing degradation by denitrification, iron reduction, sulfate reduction, and/or methanogenesis.

The concentrations and distributions of chlorinated organic compounds will be determined by analysis of groundwater samples for the compounds listed in the analytical protocol discussed in Section 3. The documentation of the anaerobic processes associated with BTEX degradation which are listed above will also be addressed by the collection of the appropriate data in the field. All of this information will be used to determine the occurrence of biodegradation of chlorinated organic compounds and the suitability of site conditions for continued biodegradation.

2.2.4 Initial Conceptual Models

Site hydrogeologic data were integrated to produce the hydrogeologic cross sections of Site 1 (ES, 1992b). Cross sections A-A' (Figure 2.3) and B-B' (Figure 2.4) show the dominant stratigraphic units present at Site 1. Figure 2.5 is a groundwater surface map using February 1990 water table elevation data (ES, 1992b).

In the vicinity of the site, groundwater exists under semiconfined conditions in glacially deposited, fine- to medium-grained sands, silts, and gravels. The saturated thickness of the aquifer in the Site 1 area is approximately 10 feet. Based on available data, Parsons ES will model the site as an unconfined to semiconfined, fine- to medium-grained sand and gravel aquifer. Groundwater is believed to flow south and southeast at the site. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Free product has been documented at Site 1 (Figure 2.8). Therefore, it will be necessary to use the fuel/water partitioning model of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-phase product into the groundwater. In order to use this model, samples of free product will be collected and analyzed for mass fraction of BTEX compounds.

2.2.5 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as storm drains, groundwater discharge points, and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration paths for hydrocarbon contaminants at the site are from the contaminated soil and the soil in the former location of the four 25,000-gallon USTs to the groundwater, and from the groundwater to potential receptors via consumption or other use. Shallow groundwater beneath Site 1 flows to the southeast towards an intermittent stream and Walnut Creek (Figure 2.1). It is unlikely that detectable concentrations of contaminants will reach either the intermittent stream or Walnut Creek because of the processes of dilution, dispersion, and degradation. If contaminated groundwater is discharged into the intermittent stream drainage or Walnut Creek, a completed pathway to human and ecological receptors may exist. Groundwater contamination is not known to have migrated beyond the boundaries of the Base. It is unlikely that exposure to contaminated groundwater from the shallow surficial aquifer may be a completed pathway to human receptors because the shallow aquifer is separated from the deeper unconsolidated aquifer by over 40 feet of relatively impermeable clay material. Primary potable water supplies for the Base and the City of Lockbourne are obtained from the deep unconsolidated aquifer.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to evaluate whether natural attenuation of fuel-related contaminants is occurring, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics include:

- Depth from measurement datum to the groundwater surface in existing monitoring wells;
- Locations of potential groundwater recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimation of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of free- and residual-phase product.

Chemical hydrogeologic characteristics include:

- Dissolved oxygen (DO) concentration;
- Specific conductance;
- pH;
- Chemical analysis of free product to determine mass fraction of BTEX; and
- Chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

Field work described in this work plan in support of the TS will be completed in February and March 1995. The objective of the field work will be to define the extent of residual and free-phase hydrocarbon contamination using CPT in conjunction with laser induced fluorescence (LIF) testing and limited soil sampling. These activities will also include groundwater monitoring point installation; CPT testing; and groundwater, free product, and soil sampling.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUND WATER AND SOIL

SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe^{2+})	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe^{3+})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	HACH 16046 DO Meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}] and Bicarbonate [HCO_3^-])	F = Titrimetric, HACH Method 8221 L = EPA method 310.1	F L
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
VOC	RSKSOP-148	L
Total Hydrocarbons	RSKSOP-174	L
FREE PRODUCT		
BTEX Mass Fraction	GC/MS, Direct Injection	L

The following sections describe the procedures that will be followed when performing field investigations and collecting site-specific data. The CPT/LIF system is described in Section 3.1. Procedures for soil sample collection to verify CPT/LIF data are described in Section 3.1.2. Procedures for the installation of new monitoring points are described in Section 3.2. Procedures for sampling existing groundwater monitoring wells and newly installed groundwater monitoring points are described in Section 3.3. Sample handling procedures are described in Section 3.4, and procedures for the measurement of aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.5.

3.1 CONE PENETROMETRY

Subsurface conditions at the site will be characterized using CPT coupled with LIF. Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring the resistance against the conical probe of the penetrometer as it is pushed into the subsurface. Stratigraphy is determined from a correlation of the point stress at the probe tip and frictional stress on the side of the cone. Soil samples are collected to correlate the CPT readings to the lithologies present at the site.

CPT will be conducted using the US Army Corps of Engineers' (USACE's) cone penetrometer truck. This equipment consists of an instrument probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is housed in a stainless steel, dual-compartment body mounted on a 43,000-pound, triple-axle Kenworth® truck chassis powered by a turbo-charged diesel engine. The weight of the truck and equipment is used as ballast to achieve the overall push capability of 39,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the 1.40-inch outside-diameter (OD) push rods, rather than by the weight of the truck. The current 39,000-pound limitation is intended to minimize the possibility of push-rod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions, having a 1.40-inch-OD, a 60-degree conical point with sacrificial tip, and an 8.0-inch-long by 1.40-inch-OD friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross-section which is instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometry truck. A grout tube also runs down the push cylinder to allow the introduction of cement grout to the hole in order to seal the CPT hole. The USACE CPT is not equipped to monitor pore pressure; therefore, the location of the water table will not be measured using the CPT apparatus. Evaluation of point and sleeve stresses can often provide an estimated depth to groundwater. The penetrometer is usually advanced vertically into the soil at a constant rate of 2 centimeters per second (cm/s), although this rate must sometimes be reduced, such as when hard layers are encountered. Penetration, dissipation, and

resistivity data will be used to determine potential site layering as it is encountered in the field.

The known propensity of aromatic hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology, in conjunction with CPT technology, to detect soil characteristics and hydrocarbon contamination simultaneously. The LIF is not capable of detecting chlorinated solvents. The LIF is only useful for more grossly contaminated areas with free-phase or significant residual contamination. The lower range of detection is greater than 100 ppm total hydrocarbons. The LIF system has a 0.25-inch sapphire window in the side of the cone that allows a laser to scan the soil for fluorescent compounds as the LIF penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are simultaneously solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. Fiber optic cables connected to the laser spectrometer and a 6-pair electrical conductor connected to the CPT data acquisition system, are routed through the interior of the push tubes to the CPT probe.

The basic components of the LIF instrument are a nitrogen laser, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The fiber optic probe for the cone penetrometer consists of delivery and collection optical fibers, a protective sheath, a fiber optic mount within the cone, and a 0.25-inch sapphire window (Figure 3.1).

The results of each LIF/CPT push will be available 2 or 3 minutes after the completion of each hole. Graphs showing cone resistance, sleeve friction, soil classification, fluorescence intensity, and wavelength will be plotted by USACE personnel at the conclusion of each penetration and presented to the Parsons ES field scientist in order to allow investigative decisions to be based on the most current information.

3.1.1 CPT/LIF Testing Strategy

The purpose of the LIF/CPT testing at the site is to determine subsurface stratigraphy and to better define the areal and vertical extent of residual fuel hydrocarbons in the unsaturated zone and free-phase hydrocarbons on the site groundwater. The CPT will be pushed from ground surface to below fluorescing contamination, refusal, or up to 40 feet bgs, depending on contaminant distribution and subsurface conditions. In order to define the edges of LNAPL contamination, CPT/LIF points will be placed at the locations shown on Figure 3.2. Most of the points will be used to define the LNAPL layer previously encountered in monitoring wells MW-5 and MW-1 (Figure 2.8). Points will be placed at the estimated outer extent of the LNAPL, and between the two monitoring wells to establish whether the product layer is continuous. CPT/LIF points will also be placed closer or further away as necessary to define the extent of the layer. Other CPT/LIF sites are located downgradient of the location of the four removed USTs, near shallow soil boring AB15, north of Building 560 in the vicinity of shallow soil boring AB1, downgradient

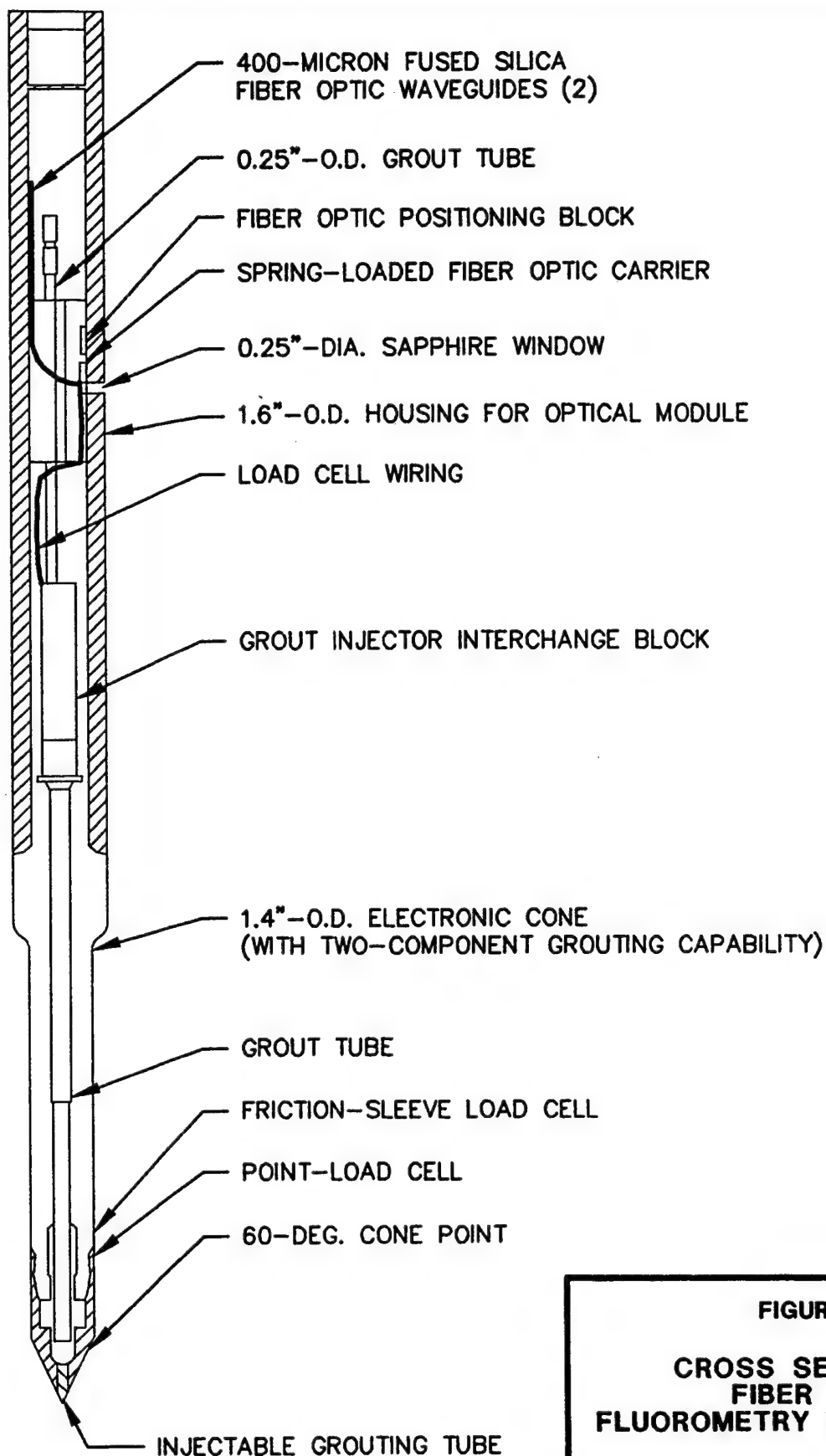


FIGURE 3.1

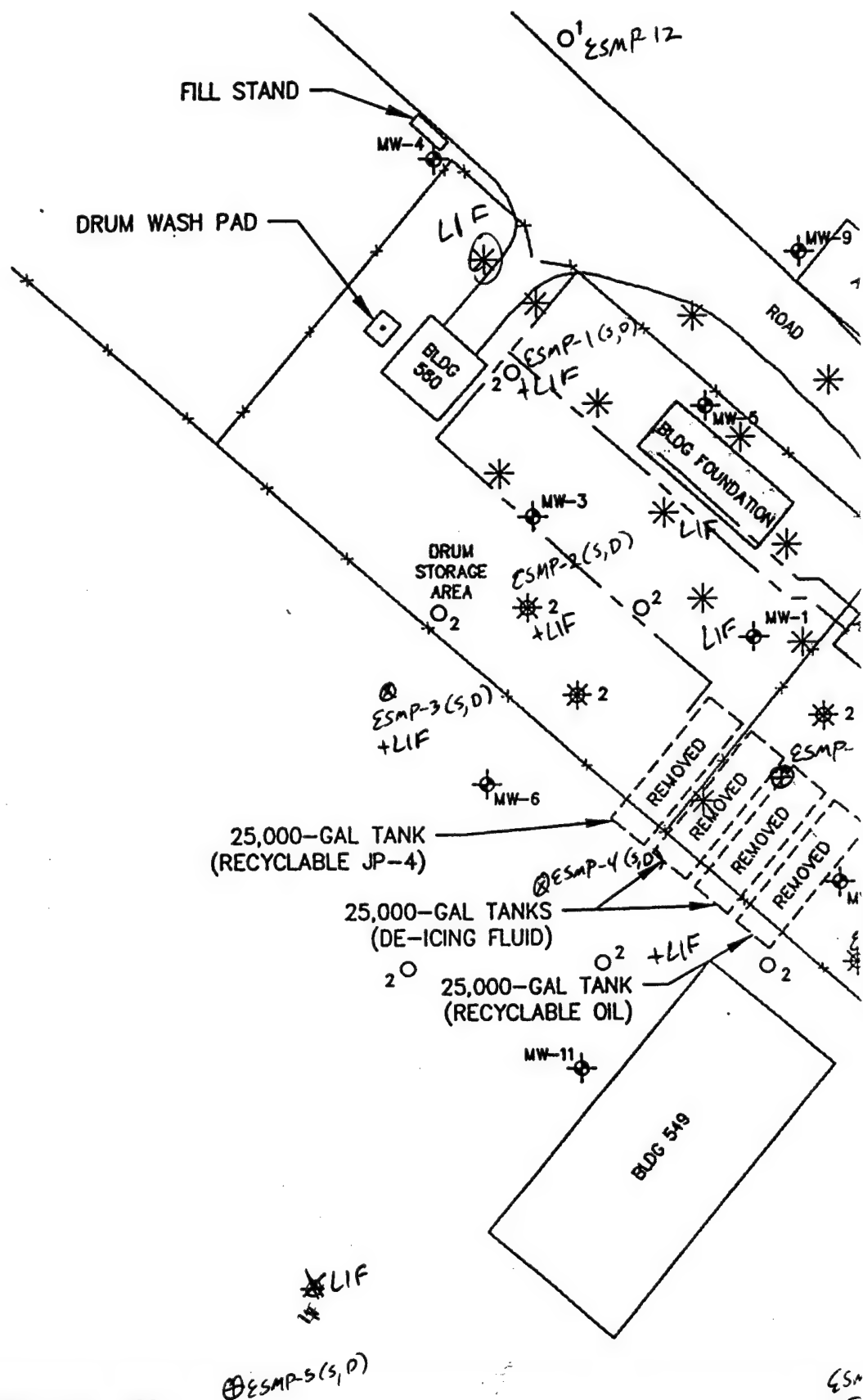
**CROSS SECTION OF
FIBER OPTIC
FLUOROMETRY PENETROMETER**

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



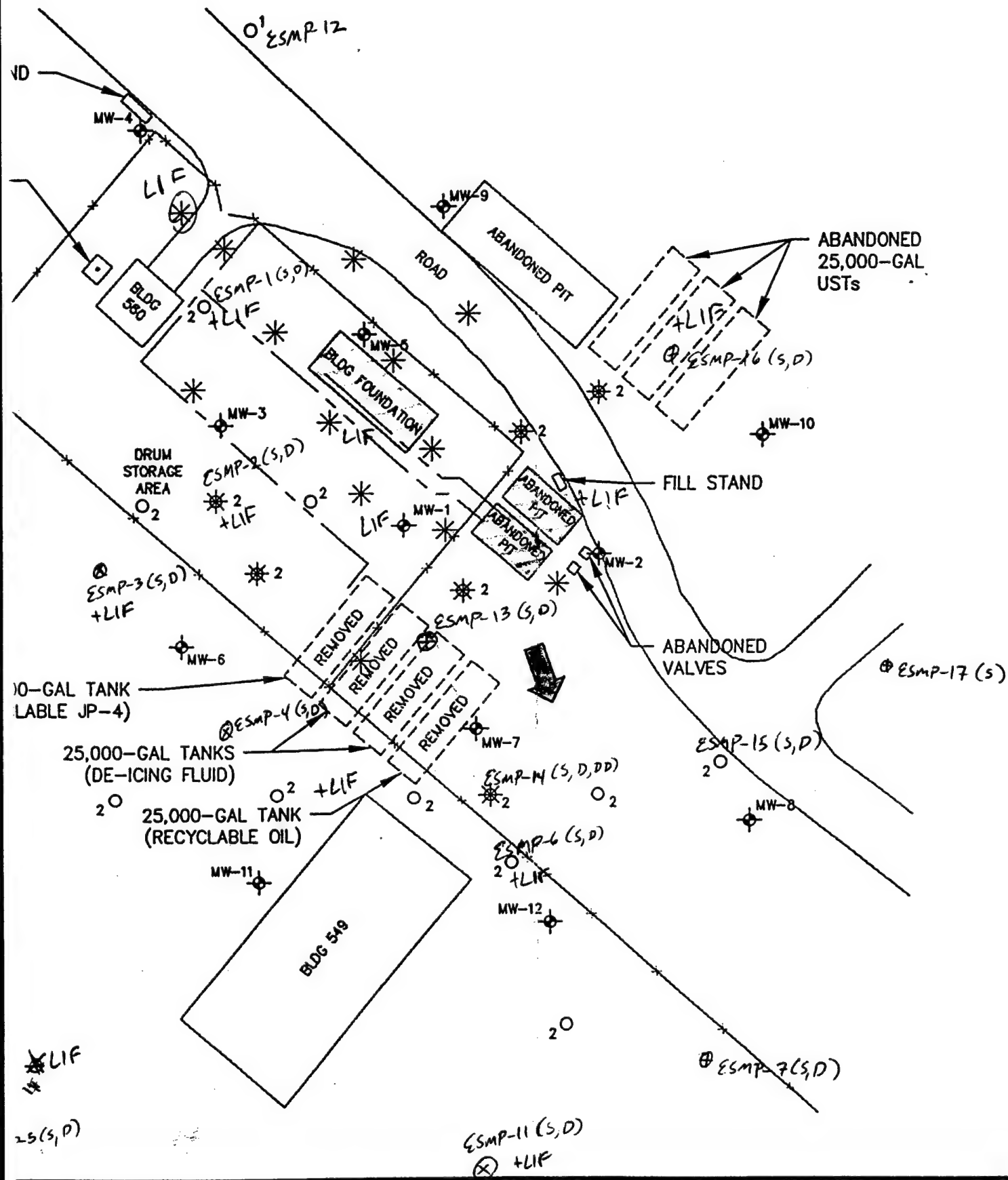
**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado



Source: ES, 1989, 1992a, 1992b and 1992c

M: \45025\DRAWINGS\95DN0201, 2/13/95 at 11:30



LEGEND



MONITORING WELL LOCATION



PROPOSED CPT/LIF LOCATION



PROPOSED MONITORING POINT
INSTALLATION AND GROUND
WATER SAMPLING LOCATION
WITH NUMBER OF PROPOSED
MONITORING POINTS



ABANDONED FUEL LINE



FENCE



GROUND WATER FLOW
DIRECTION



- Known concrete slabs exist

ABANDONED
25,000-GAL
USTs

ESMP-16 (S,D)

MW-10

FILL STAND

ABANDONED
VALVES

ESMP-17 (S)

ESMP-15 (S,D)
2

MW-8

ESMP-7 (S,D)

N

0 20 40 80
FEET

FIGURE 3.2

PROPOSED CONE PENETROMETER AND GROUND WATER SAMPLING LOCATIONS

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

of the abandoned separator pits, and downgradient of Building 560 near soil boring HB-1.

Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, and any other underground infrastructure prior to any CPT activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed CPT/LIF locations indicated in Figure 3.2.

3.1.2 Soil Sampling and Analysis

To check the CPT soil classifications and to calibrate the LIF data, soil samples from discrete intervals will be collected at the site. Soil samples will be collected from varied soil matrices (if present) from within source areas and visibly contaminated areas, at the fringe of the identified residual or light nonaqueous-phase liquid (LNAPL) hydrocarbon plume, and outside of the LNAPL plume.

When soil samples are collected using the CPT, a Hoggen Toggler[®] attachment for the CPT push rods will be used. A Hoggen Toggler[®] sampler is a device used to collect undisturbed soil samples at any desired depth within the range of the driving apparatus. The sampler is coupled to the penetrometer rod and pushed into the soil with the CPT truck. With the Hoggen Toggler[®] cone in the closed position, soil is prevented from entering the sampling tube until the desired depth is achieved. When the sampler has been pushed to the depth at which the soil sample is to be taken, the sampling unit is raised a few inches and the Hoggen Toggler[®] apparatus is opened. The open Hoggen Toggler[®] is pushed to fill with soil, then pulled from the ground as quickly as possible. The Hoggen Toggler[®] sampling apparatus allows collection of 8-inch-long by 1-inch inside-diameter (ID) continuous samples. Recovery efficiencies for samples in saturated or sandy soils are often reduced, or the samples are compromised, because of spillage of the soil from the device after extraction. To mitigate this problem, soil samples will be compressed *in situ* with the penetrometer and Hoggen Toggler[®] assembly to expel the pore water before extraction.

When the Hoggen Toggler[®] sampling technique described above is ineffective or unable to efficiently provide sufficient soil volumes for the characterization of the site, soil samples will be obtained using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

Recovered soil will be placed in analyte-appropriate sample containers (Appendix A) and shipped to the analytical laboratory for analysis of BTEX, total organic carbon (TOC), moisture content, and total petroleum hydrocarbons (TPH) by the analytical methods listed in Table 3.1. The lithology of recovered soil will be recorded for comparison and correlation with CPT results.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly

labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.3. The descriptive log will contain the following information:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination based on visual observations, odor, and photoionization detector (PID) headspace VOC measurements;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

3.1.3 CPT Locations and Datum Survey

The horizontal location of all CPT/LIF testing locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured to the nearest 0.1 foot relative to a USGS msl datum. Sample location and other relevant site information for the soil cores collected for verification purposes will be recorded by the Parsons ES field scientist.

3.1.4 Site Restoration

After sampling is complete, each CPT site will be restored as closely to its original condition as possible. Any test holes remaining open after extraction of the penetrometer rod will be sealed with hydrated bentonite chips, pellets, or grout to eliminate the creation or enhancement of contaminant migration pathways to the groundwater.

3.1.5 Equipment Decontamination Procedures

The CPT push rods will be cleaned with potable water using the USACE CPT steam-cleaning system (rod cleaner) as the rods are withdrawn from the ground. A vacuum system located beneath the CPT truck will be used to recover rinseate. Use of this system results in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner. Rinseate is generated only as the rods move past the cleaner, thereby minimizing liquid waste generation. Care will be taken not to apply the pressurized steam to the LIF module, which will be decontaminated by hand. Rinseate will be collected in 55-gallon drums. Filled 55-gallon drums will be stored at the Base, and Base personnel will arrange for final disposal of the drums and their contents. Base personnel are responsible for sampling the contents of the drums to identify any hazardous constituents before the drums are transported to an appropriate disposal facility.

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: AFCEE RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: 722450.25 DRLG METHOD: _____ ELEVATION: _____
 LOCATION: RICKENBACKER ANGB BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB


 Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Site 1 (HWSA)
 Intrinsic Remediation TS
 Rickenbacker Air National Guard Base, Ohio

 **PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Other downhole and sampling equipment will be decontaminated by steam cleaning or by the procedures specified in Section 3.3.1.1.

Potable water to be used in CPT equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact on the surrounding area that might result from decontamination operations.

3.2 PERMANENT MONITORING POINT INSTALLATION

To further characterize the hydrogeologic conditions of the shallow subsurface, up to 33 groundwater monitoring points may be installed at Site 1 to supplement the existing site monitoring wells. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

3.2.1 Monitoring Point Locations and Completion Intervals

The locations of 33 proposed groundwater monitoring points are identified for Site 1 on Figure 3.2. The proposed locations for the new monitoring points were determined from a review of existing data gathered during previous site activities. Monitoring point locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Monitoring point locations were selected to define three aspects of Site 1: 1) the extent of contamination, 2) the horizontal and vertical distribution of dissolved BTEX, and 3) the hydrogeology and groundwater flow direction at the site. The proposed locations shown on Figure 3.2 may be modified in the field as a result of encountered field conditions and acquired field data.

Several shallow monitoring points are proposed to define the extent of the primary contaminant plume, which emanates from the northwest corner of the building foundation and extends southeast to the four former 25,000-gallon USTs. Ten nested pairs of monitoring points are proposed to be located within and along the southeast, southwest, and northeast borders of the estimated primary dissolved BTEX plume to define the lateral and vertical extent of contaminant migration. Of these 10, three nested pairs of monitoring points will be located adjacent to and downgradient of the former location of the four 25,000-gallon USTs, to determine if any contamination is associated with the USTs.

Six additional nested pairs of monitoring points will be positioned to assess the extent of contamination not associated with the primary contaminant plume. One nested pair will be located downgradient of the abandoned pit northeast of the building foundation and one nested pair will be situated southeast of Building 560. The remaining four nested pairs will be placed to the south and southeast of monitoring well MW-3 to define the horizontal and vertical extent of contamination originating in the DSA.

A single shallow monitoring point will be located north of the road leading in to Site 1 from the northwest. This point will be utilized to determine background contamination concentrations and geochemical parameters.

Screened intervals for shallow monitoring points will extend from approximately 4 feet above the water table to 2 feet below the water table. Deep points will be placed on the basis of lithology, or approximately 5 feet below the next shallowest monitoring point (in the absence of significant lithologic changes). Deep monitoring points will be installed with 1 meter of screen. The shallow monitoring points will be installed with 2 meters of screen in order to accommodate the seasonal groundwater elevation fluctuations (Table 2.2). The proposed screened intervals of 2 meters for shallow monitoring points and 1 meter for deep monitoring points will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated groundwater in the monitoring point casing, and will give important information on the nature of vertical hydraulic gradients in the area. Adjustments of the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distribution identified during CPT/LIF testing.

3.2.2 Monitoring Point Installation Procedures

This section describes the procedures to be used for installation of new groundwater monitoring points. All new monitoring points will be constructed of 0.75-inch OD/0.5-inch-ID polyvinyl chloride (PVC) casing placed with a CPT pushrod using equipment described in Section 3.1.

3.2.2.1 Pre-Placement Activities

All necessary digging, drilling, and groundwater monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Ground Water Monitoring Point Installation

3.2.2.2.1 Monitoring Point Materials Decontamination

Monitoring point completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.2.2 Monitoring Point Screen and Casing

Groundwater monitoring points will be installed by attaching 0.75-inch-OD/0.5-inch-ID PVC casing and screen to a sacrificial tip and threading the casing/screen through the penetrometer pushrod. As the pushrod is pressed into the ground, new 0.75-inch-OD/0.5-inch-ID PVC casing will be continuously attached until the desired depth is reached and a fully cased monitoring point is created. Data collection devices such as CPT and LIF will not be used during monitoring point placement; however, a CPT test will be performed at each monitoring point location prior to monitoring point placement in order to select desired screen depths.

Monitoring point casing and screens will be constructed of flush-threaded Schedule 40 PVC. The screens will be factory slotted with 0.01-inch openings. Casing joints will not be glued. The PVC top cap will be vented to maintain ambient atmospheric pressure if the monitoring point is completed above grade. The PVC top cap for monitoring points completed at or below grade will not be vented to minimize the potential for runoff or surface water entering the point.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be recorded to the nearest 0.1 foot. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

3.2.2.3 Above-Grade and At-Grade Well Completion

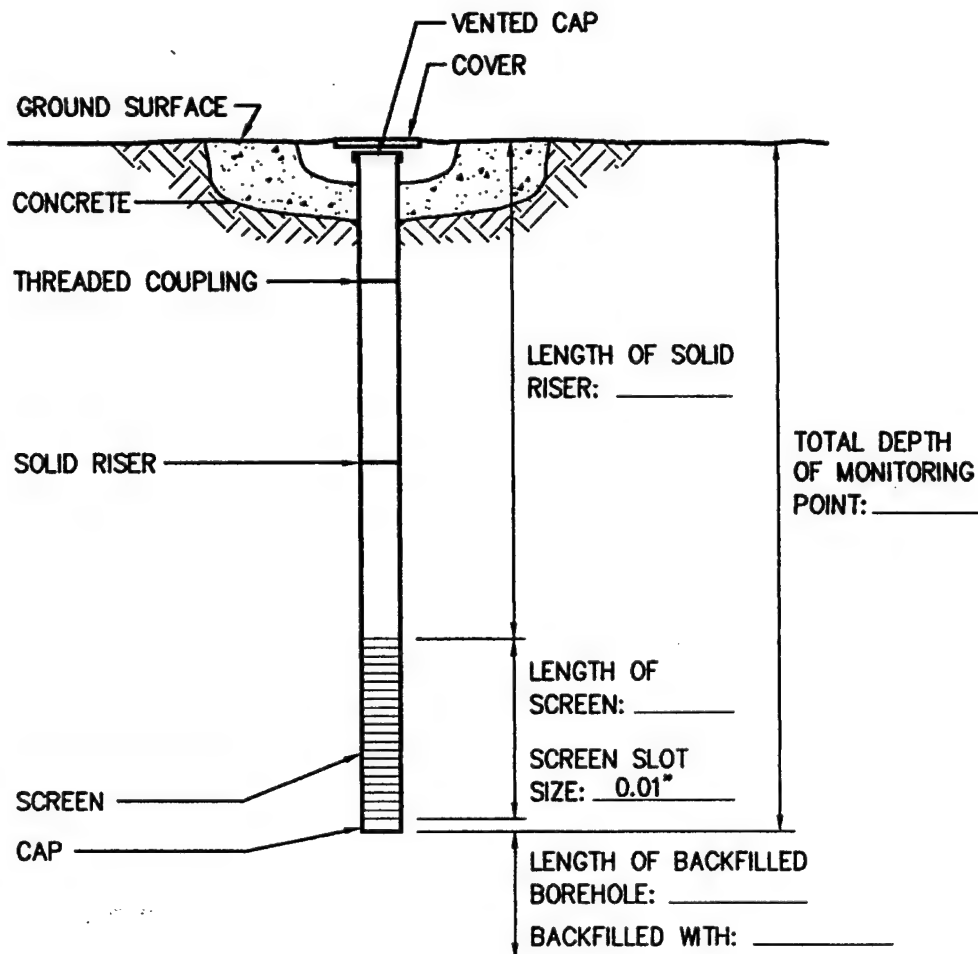
Each monitoring point will be completed with an at-grade protective cover or an above-grade protector pipe. In areas where pavement is present, the at-grade cover will be cemented in place using concrete blended to the existing pavement; otherwise, a concrete pad will be installed around the monitoring point. The concrete immediately surrounding the monitoring point will be sloped gently away from the protective casing to facilitate runoff during precipitation events. For above-grade completions, a steel protector pipe will be installed around the monitoring point riser in order to protect the riser from damage. Each pipe will be painted a color designated by Base personnel and cemented into a 1-foot-square pad to ensure the stability of the post.

3.2.2.4 Monitoring Point Development

New monitoring points will be developed prior to sampling. Development removes sediment from inside the monitoring point casing and flushes fines from the portion of the formation adjacent to the monitoring point screen.

Monitoring point development will be accomplished using a peristaltic pump with dedicated tubing provided by Parsons ES. The pump tubing will be regularly lowered to the bottom of the monitoring point so that fines which have accumulated in the bottom are agitated and removed from the monitoring point.

JOB NAME RICKENBACKER AIR NATIONAL GUARD BASE MONITORING POINT NUMBER _____
 JOB NUMBER 722450.25 INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL _____ SLOT SIZE _____
 RISER DIAMETER & MATERIAL _____ BOREHOLE DIAMETER _____
 CONE PENETROMETER CONTRACTOR _____ ES REPRESENTATIVE _____



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 TOTAL MONITORING POINT DEPTH _____ FEET
 BELOW DATUM.
 GROUND SURFACE _____ FEET

FIGURE 3.4

Site 1 (HWSA)
 Intrinsic Remediation TS
 Rickenbacker Air National Guard Base, Ohio



**PARSONS
 ENGINEERING SCIENCE, INC.**

Denver, Colorado

Development will be continued until a minimum 10 casing volumes of water has been removed from the monitoring point and until pH, temperature, specific conductivity, DO, and water clarity (turbidity) stabilize. If the water remains turbid, monitoring point development will continue until the turbidity of the water produced has been stable after the removal of several casing volumes.

A monitoring point development record will be maintained for each point. The monitoring point development record will be completed in the field by the field scientist. Figure 3.5 is an example of the monitoring point development record. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Pre-development water level and monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected in 55-gallon drums. Filled 55-gallon drums will be placed on pallets and transported by Base personnel to the Base's designated hazardous waste collection area.

3.2.2.5 Water Level Measurements

Water levels at existing monitoring wells and newly installed monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

3.2.2.6 Monitoring Point Location and Datum Survey

The location and elevation of the new monitoring points will be surveyed soon after point completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the monitoring point casing and the measurement datum elevation (top of PVC casing) will be measured relative to the USGS msl datum. The ground surface elevation will be measured to the nearest 0.1 foot and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: 722450.25020
Location Site 1 HWSA
Well Number _____

Job Name: Rickenbacker ANGB
By _____ Date _____
Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(^oF ^oC) _____
Specific Conductance(μ S/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (^oF ^oC) _____

Specific Conductance(μ S/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(^oF ^oC) _____
Specific Conductance(μ S/cm) _____

Comments: _____

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

3.2.3 Site Restoration

After monitoring point installation and sampling is complete, each site will be restored around the finished monitoring point as closely as possible to its original condition. Both clean and contaminated development waters and sampling purge waters will be stored in 55-gallon drums and transported by Base personnel to the designated area used for collection of hazardous wastes at the Base.

3.3 GROUNDWATER SAMPLING

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from existing monitoring wells (i.e., wells MW-1 through MW-12) and newly installed groundwater monitoring points. A peristaltic pump with dedicated high-density (HDPE) tubing will be used to collect groundwater samples. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parson ES and the EPA/Robert S. Kerr Research Laboratory (RSKERL) who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. The following activities will occur during groundwater sampling:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Monitoring point stick-up, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including
 - Water level and product thickness measurements,
 - Visual inspection of sample water,
 - Monitoring point casing evacuation, and
 - Sample collection;
- Sample preservation and shipment, including
 - Sample preparation,
 - Onsite measurement of physical parameters, and
 - Sample labeling;
- Completion of sampling records: and

- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the CPT soil sampling tool, water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the EPA mobile laboratory's permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, pH, electrical conductivity, temperature, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling; _____ (number)

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT _____

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT _____

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____

Items Cleaned (List): _____

2 ☐ PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM

Measured with: _____

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: _____

Odor: _____

Other Comments: _____

4 ☐ WELL EVACUATION:

Method: _____

Volume Removed: _____

Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

FIGURE 3.6

GROUND WATER
SAMPLING RECORD

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

contact with improperly cleaned equipment and through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well or monitoring point developed, purged, and/or sampled with the peristaltic pump. The nondisposable bailers will be decontaminated according to procedures listed in Section 3.3.1.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled. Dedicated, disposable bailers may be used on the 2-inch ID existing wells. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point and the depth will be measured to the nearest 0.01 foot. If free-phase product (LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If free-phase product is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.3.2.3 Monitoring Well/Point Purging

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well/point. All purge water will be placed in 55-gallon drums and disposed of by Base personnel in the Base's approved disposal location. Emptied 55-gallon drums will be handled by Base personnel. A peristaltic pump will be used for monitoring well and monitoring point purging, depth permitting, and either a Waterra[®] inertial pump or bailer will be used to purge all monitoring points in which a peristaltic pump will not work.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring wells/points whenever depth to groundwater permits; otherwise, a Waterra[®] inertial pump or bailer will be used. The tubing, pump, or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the EPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for monitoring well/point purge waters and transported for disposal by Base personnel to the facilities designated by the Base.

3.3.3 Onsite Ground Water Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by EPA/RSKERL staff. Some of the measurements will be made with direct-reading meters, while others will be made using of a HACH[®] portable colorimeter in accordance with specific HACH[®] analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox[®] and water, and rinsing with deionized water and isopropyl alcohol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer by Base personnel to the approved disposal facility.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following groundwater sample acquisition. When DO measurements are taken in monitoring wells/points that have

not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.3.3.3 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced EPA/RSKERL scientists via titrimetric analysis using EPA-approved HACH[®] Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater sample will also be measured in the laboratory using EPA method 310.1.

3.3.3.4 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced EPA/RSKERL scientists via colorimetric analysis using a HACH[®] DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH[®] Method 8039 (0 to 30.0 mg/L NO₃). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH[®] Method 8507 (0 to 0.35 mg/L NO₂) or a similar method.

3.3.3.5 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by EPA/RSKERL scientists via titrimetric analysis using HACH[®] Method 8223 (0 to 250 mg/L as CO₂). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3.3.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate

reduction. An EPA/RSKERL scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. EPA-approved HACH® Methods 8051 (0 to 70.0 mg/L SO₄) or similar and 8131 (0.60 mg/L S²⁻) or similar will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the redox potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L Fe³⁺ + Fe²⁺) and HACH® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe²⁺) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. EPA approved HACH® Method 8034 (0 to 20.0 mg/L) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Redox Potential

The redox potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in the upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to EPA mobile laboratory.

3.4.1 Sample Preservation

The EPA laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C). Samples will be delivered promptly to EPA mobile laboratory personnel, who will be responsible for shipment of appropriate samples to the RSKERL in Ada, Oklahoma for analysis.

3.4.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the EPA mobile laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite EPA mobile laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the EPA mobile laboratory. Delivery will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the EPA mobile laboratory to the EPA/RSKERL analytical laboratory in Ada, Oklahoma, will be the responsibility of the EPA/RSKERL field personnel.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;
- Water level prior to purging (groundwater samples, only);
- Total monitoring well/point depth (groundwater samples, only);
- Sample depth (soil samples, only);
- Purge volume (groundwater samples, only);
- Water level after purging (groundwater samples, only);
- Monitoring well/point condition (groundwater samples, only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples, only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 5. The analytical methods for this

sampling event are listed in Table 3.1. Prior to sampling, EPA/RSKERL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA protocol or those reported in Appendix A of this plan.

EPA/RSKERL laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media may be provided by EPA/RSKERL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the mobile laboratory.

3.5 AQUIFER TESTING

Slug tests will be conducted on selected existing wells to estimate the hydraulic conductivity of unconsolidated sand and clay deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon®, PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger®, In-Situ, Inc. Model SE1000B, or equivalent).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following paragraphs describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:

- Borehole/well number,
- Project number,
- Project name,
- Aquifer testing team,
- Climatic data,
- Ground surface elevation,
- Top of well casing elevation,
- Identification of measuring equipment being used,
- Page number,
- Static water level, and
- Date.

4. Measure the static water level in the well to the nearest 0.01 foot.

5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.

6. Lower the decontaminated slug into the well to just above the water level in the well.

7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.

8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following paragraphs describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.

Location _____	Client _____	Well No. _____
Job No. _____	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]**FIGURE 3.7**

AQUIFER SLUG TEST DATA FORM

Site 1 (HWSA)
Intrinsic Remediation TS
Rickenbacker Air National Guard Base, Ohio



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of fuel hydrocarbons dissolved in groundwater at the site. Based upon model predictions of contaminant concentrations and distribution through time, and upon potential exposure pathways, the potential threat to human health and the environment based on regulatory action levels will be assessed. If it is shown that intrinsic remediation of BTEX compounds at the site is sufficient to reduce concentrations to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation option is deemed inappropriate for use at this site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the contaminant concentrations to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free-product recovery, groundwater pump-and-treat, enhanced biological treatment, bioventing, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, an TS report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model simulations developed for this site.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

INTRODUCTION

Scope and Objectives
Site Background

SITE CHARACTERIZATION ACTIVITIES

CPT, Sampling, and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features
Regional Geology and Hydrogeology
Site Geology and Hydrogeology
Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization
Soil Chemistry
 Residual-Phase Contamination
 Total Organic Carbon
Ground Water Chemistry
 LNAPL Contamination
 Dissolved Contamination
 Ground Water Geochemistry
 Expressed Assimilative Capacity

GROUND WATER MODEL

Model Description
Conceptual Model Design and Assumptions
Initial Model Setup
Model Calibration
Sensitivity Analysis
Model Results
Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial Alternative Evaluation Criteria
 Long-Term Effectiveness
 Implementability (Technical, Administrative)
 Cost (Capital, Operating, Present Worth)
Factors Influencing Alternatives Development
 Program Objectives
 Contaminant Properties
 Site-Specific Conditions
Brief Description of Remedial Alternatives

TABLE 4.1 (Continued)
EXAMPLE TS REPORT OUTLINE
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Intrinsic Remediation with Long-Term Monitoring
Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach
LONG-TERM MONITORING PLAN
Overview
Monitoring Networks
Ground Water Sampling
CONCLUSIONS AND RECOMMENDATIONS
How does the recommended technology offer adequate protection for less cost.
APPENDICES: Supporting Data and Documentation
Site-Specific Bioplume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field, and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to an onsite or offsite analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used and packaged in coolers with ice to maintain a temperature of approximately 4 °C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

One duplicate sample will be collected for every 10 or fewer samples collected, both for groundwater and soils. Volume permitting, duplicate samples will be collected at locations where low to moderate levels of contamination are believed to be present.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected from existing wells. If disposable bailers are used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a new disposable bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs by Method RSKSOP-148.

A field blank will be collected for every 20 or fewer groundwater samples (both from groundwater monitoring point and existing groundwater monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample

TABLE 5.1

QA/QC SAMPLING PROGRAM
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytes or Analytical Methods
Duplicates/Replicates	10% of Samples per Matrix ^{a/}	VOCs, TPH
Rinseate Blanks	10% of Ground Water Samples ^{a/}	VOCs
Field Blanks	5% of Ground Water Samples ^{a/}	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

^{a/} Rounded to the next highest whole number.

container while sampling activities are underway. The field blank will be analyzed for VOCs by Method RSKSOP-148.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

REFERENCES

- Borden, R.C., and Bedient, P.B., 1986. Transport of dissolved hydrocarbons influenced by oxygen limited biodegradation theoretical development, *Water Resources Research*, vol. 22, no. 13. p. 1973-82.
- Bouwer, H., 1989, The Bouwer and Rice slug test - an update: *Ground Water*, 27(3), p. 304-309.
- Bouwer, H., and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: *Water Resources Research*, 12(3), p. 423-428.
- Bruce, L., Miller, T., and Hockman, B., 1991, Solubility versus equilibrium saturation of gasoline compounds - a method to estimate fuel/water partition coefficient using solubility or K_{oc} ... In, A. Stanley (editor), *NWWAI/API Conference on Petroleum Hydrocarbons in Ground Water*: NWT/API, p. 571-582.
- Cline, P.V., Delfino, J.J., and Rao, P.S.C., 1991, Partitioning of aromatic constituents into water from gasoline and other complex solvent mixtures: *Environmental Science and Technology*: v. 17, no. 4, p. 227-231.
- Driscoll, F.G., *Groundwater and Wells*, Second Edition: Johnson Filtration Systems, Inc., St. Paul, MN, 1986.
- Engineering Science, Inc.(ES), 1989, *Final Field Investigation Report Hazardous Waste Storage Area, Rickenbacker Air National Guard Base, Columbus, Ohio*, April.
- Engineering-Science, Inc. (ES), 1992a, *Final Addendum to the Pre-Closure Sampling Report Hazardous Waste Storage Area, Rickenbacker Air National Guard Base, Columbus, Ohio*, January.
- Engineering-Science, Inc. (ES), 1992b, *Final Pre-Closure Sampling Report Hazardous Waste Storage Area, Rickenbacker Air National Guard Base, Columbus, Ohio*, March.
- Engineering-Science, Inc. (ES), 1992c, *Determination of Phase-Separated Hydrocarbon Extent at the Hazardous Waste Storage Area, Rickenbacker Air National Guard Base, Columbus, Ohio*, March.

- Engineering-Science, Inc. (ES), 1993a, *Amended Closure / Post Closure Plan Hazardous Waste Storage Area (Building 56), Rickenbacker Air National Guard Base, Columbus, Ohio*, March.
- Engineering-Science, Inc. (ES), 1993b, *Health and Safety Plan for the Bioplume Modeling Initiative*. Prepared for the Air Force Center for Environmental Excellence, Environmental Restoration Division, USAF Contract F41624-92-D-8036.
- Espenshade, E.B., *Goode's World Atlas*, 17th Edition: Rand MacNally & Company, San Francisco, CA, 1986.
- Hazardous Materials Technical Center, 1987, *Installation Restoration Program: Phase 1, Records Search (Preliminary Assessment), Rickenbacker Air National Guard Base, Columbus, Ohio*, June.
- Hvorslev, M. J., 1951, *Time Lag and Soil Permeability in Ground-Water Observations*: United States Corps of Engineers Waterways Experiment Station Bulletin 36, Vicksburg, Mississippi. 50 p.
- Lee, M.D., 1988. "Biore Restoration of Aquifers Contaminated with Organic Compounds." *CRC Critical Reviews in Environmental Control*, v. 18. p. 29-89.
- Pierce, L.J., *The Climate of Ohio: in Climates of the States, 1959*, In Volume 1 - Eastern States, Water Information Center, Inc., 1974.
- Rifai, H.S., Bedient, P.B., Wilson, J.T., Miller, K.M., and Armstrong, J.M., 1988, Biodegradation modeling at aviation Fuel spill site, *Journal of Environmental Engineering*, v. 114, no. 5, p. 1007-1029.
- US Geological Survey (USGS), 1985, 7.5 Minute Quadrangle Map of Lockbourne, Ohio.
- Wiedemeier, T. H., Downey, D. C., Wilson, J. T., Kampbell, D. H., Miller, R. N., and Hansen, J. E., In Preparation, *Technical Protocol for Implementing the Intrinsic Remediation (Natural Attenuation) with Long-term Monitoring Option for Dissolved-phase Fuel Contamination in Ground Water*. Prepared for the Air Force Center for Environmental Excellence.

APPENDIX A

**CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING
REQUIREMENTS FOR GROUND WATER SAMPLES**

TABLE A.1
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–1.5 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe ⁺²)	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{2+})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO)	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are suspected of undergoing biological transformation	Ethane and ethene are products of the biotransformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITE 1 (HWSA)

INTRINSIC REMEDIATION TS
RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Temperature	E170;1	Field only	Well development	Each sampling round	N/A	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS

SITE 1 (HWSA)

INTRINSIC REMEDIATION TS

RICKENBACKER AIR NATIONAL GUARD BASE, OHIO

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE Environmental Chemistry Function Installation Restoration Program Analytical Protocols, 11 June 1992.
5. "Handbook" refers to the AFCEE Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS), September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (Environmental Protection Agency Laboratory) *Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

APPENDIX B

ADDITIONAL SITE DATA

TABLE B.1**HYDRAULIC CONDUCTIVITY AND GROUNDWATER VELOCITY**

**SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO**

Well	Hydraulic Conductivity		Velocity ^{a/}	
	(cm/sec)	(ft/day)	(ft/day)	(ft/year)
MW-1	5.76E-05	1.96	0.3682	134.39
MW-2	2.86E-04	9.72	1.8274	666.99
MW-3	2.57E-07	8.74E-03	0.0016	0.60
MW-4	5.55E-05	0.157	0.0295	10.77
MW-6	6.75E-05	0.192	0.0361	13.18
MW-7	2.00E-03	4.32	0.8122	296.44
MW-8	4.89E-05	0.139	0.0261	9.54
Average	3.59E-04	2.356	0.4430	161.70

Source: ES, 1989 and 1992b

^{a/} Assuming porosity of 0.25 and hydraulic gradient of 0.047 ft/ft.

TABLE B.2

SOIL-GAS SURVEY RESULTS, JULY 25, 1988

SITE 1 (HWSA)

INTRINSIC REMEDIATION TS

RICKENBACKER ANGB, OHIO

Sample	Benzene (ppm)	Toluene (ppm)	O-Xylene (ppm)	Total BTEX (ppm)
1SG1-5	ND ^{a/}	ND	29.81	29.81
1SG2-5	ND	ND	ND	ND
1SG3-5	ND	ND	ND	ND
1SG4-5	ND	ND	ND	ND
1SG5-5	ND	ND	ND	ND
1SG6-5	0.49	0.1	0.07	0.66
1SG7-5	ND	ND	ND	ND
1SG8-3.5	ND	ND	ND	ND
1SG9-5	ND	ND	ND	ND

Source: ES, 1989

^{a/} Contaminant not detected

TABLE B.3

**SOIL SAMPLE HEADSPACE, JULY 1990
VOLATILE ORGANICS COMPOUNDS (VOC)**

**SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO**

Sample ID	VOC ^{a/} (µg/kg)
Abandoned Pit - RANGB (Northeast)	24.8
Separator Pit (East)	NA ^{b/}
Stockpile 1	73
Stockpile 2	80.2
Stockpile 3	950
Stockpile 4	151
SS1	ND ^{c/}
SS2	ND
SS3	1108
SS4	78
SS5	583
SS6	602
SS7	ND
SS8	373
SS9	2470
SS10	977

Source: ES, 1992b and 1992c

^{a/} Sample screened with TIP II Photoionization Detector calibrated
with 100 ppm isobutylene in air.

^{b/} Not Analyzed

^{c/} Contaminant not detected

TABLE B.4
RESULT OF GROUNDWATER VOC SCREENING
SITE 1 (HWSA)
INTRINSIC REMEDIATION TS
RICKENBACKER ANGB, OHIO

Sample ID	VOC (µg/L)
GW-1	8
GW-2-2D	ND ^{a/}
GW-3	ND
GW-4	2092
GW-5	ND
GW-6	ND
GW-7	ND
GW-8	ND
GW-9	ND
GW-10	ND
GW-11	ND
GW-12	ND
GW-13	168
GW-14	ND
GW-15-18	ND
GW-19	ND
GW-20-20D	4
GW-21	178
MW-1	PSH ^{b/}
MW-2	2
MW-3	10
MW-4	ND
MW-5	PSH
MW-6	2190
MW-7	134
MW-8	3
MW-9	ND
MW-10	ND
MW-11	ND
MW-12	ND

Source: ES, 1992b

^{a/} Contaminant not detected

^{b/} Phase separated hydrocarbons in monitoring well.